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FURTHER OBSERVATIONS ON THE MALAYSIAN COCONUT ZYGAENID (*ARTONA CATOXANTHA*, HAMPS.)

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General.

In a former issue of this journal* an account was given of the observations made by the writer on *Artona catoxantha*, together with a summary of the knowledge previously available. Up to the present there has been no opportunity of studying this pest in "normal" or "non-outbreak" times, and only three outbreaks have occurred since the publication of the last paper. One was a small one in the neighbourhood of Batu Gajah, which was, however, abortive; another occurred near Telok Anson, but was not reported until it was all over; but an outbreak of importance occurred at Kuala Dipang, and the opportunity was taken of accumulating the data given in the present paper which is in the nature of a progress report. No control measures were attempted at Kuala Dipang, because as much material as possible was required for study and for the transport of parasites to Fiji for the control of *Levuana iridescens*. Details of the latter work will be included in the paper on *Ptychomyia remota*. The outbreak was first reported in June, 1925, and ended in October following heavy rainstorms.

*"Some observations on the Malaysian Coconut Zygaenid (*Artona catoxantha*, Hamps.)" M.A.J., Vol. 13, page 92, April, 1925.

Thus it was again noticed that rain accompanied by wind was the terminating factor in outbreaks. The outbreak was not reported until it had been on some time, although this is a notifiable pest, but on examining the palms at Kuala Dipang it was noticed that the earliest infestation had occurred in the near vicinity of a large incinerator in the village, whence the attack spread to the surrounding palms. This supports the theory originally advanced that fires under the palms are connected with the incidence of outbreaks. At Kuala Dipang the caterpillars were observed to feed on banana, but this is probably in the nature of a secondary food plant used during heavy infestations, when the normal food is scarce.

Life History.

Failure to induce the moths to lay in captivity was again experienced, even when small growing palms were enclosed in large cages containing the moths. The life-history of the earlier stages was, however, worked out for the first time from egg to adult without a break. It will be remembered that the figures given for the larval stages in the previous paper were made up from a large number of observations on different individuals, it having been found that the larvae, especially in the earlier instars, would not readily live in captivity. The mortality previously experienced was undoubtedly due to handling and the partial wilting of the coconut leaves in small cages.

Rearing the larvae right through from the egg was made possible by a suggestion made by Mr. H. W. Simmonds, that a dilute solution of sulphur dioxide (sulphurous acid) would keep the leaves fresh for long periods. It is believed that Mr. Simmonds obtained the idea from Dr. J. D. Tothill, who had seen this method of keeping plants alive in use in the Philippines for plant-breeding work.* Sulphur dioxide, from a syphon of the liquified gas, was slowly bubbled through water until the concentration reached 5% SO_2. The concentration was estimated by titration with iodine solution standardised by means of sodium thiosulphate. The stock solution was then diluted as required, the pinnae of coconut leaves being placed in glass tubes, 4 x 1 inches, containing a solution of 1 in 2,000 sulphur dioxide. By this means the same portion of leaf could be allowed to remain in the cage for long periods, large glass cylinders, $9\frac{1}{4}$ x $4\frac{1}{4}$ inches, the ends of which were closed by easily removeable zinc gauze covers being used. The coconut leaf was held in place by a plug of cotton-wool. One larva, as soon as it had hatched, was placed on the under surface

*"A method of handling Cane Tassels for Breeding Work" by J. A. Verret and others, Internat. Sugar Journal, Vol. 27, page 412, August, 1925.

of the leaf in a separate cage. The records of twelve such rearings are given in Table 1:—

TABLE I.

Life Cycle.

Sex.	Time in Days.							
	Instar I	Instar II	Instar III	Instar IV	Instar V	Pupa.	Period Cocoon to pupation.	Total.
F	5	4	3	4	8	8	(2)	32
M	5	3	3	4	7	7	(2)	29
M	5	3	3	4	7	8	(2)	30
M	5	3	3	4	6	7	(3)	28
F	5	2	3	5	4	8	(2)	27
F	5	2	3	5	4	8	(2)	27
F	6	2	2	5	5	7	(2)	27
F	4	3	3	5	6	7	(1)	28
F	4	3	3	5	9	7	(1)	31
F	3	5	4	5	6	8	(2)	31
—	3	5	4	5	6	Died	—	—
F	3	6	3	7	6	8	(2)	33
Mean.	4.4	3.4	3.1	4.8	6.2	7.5	1.9	29.4
Range	3-6	2-6	3-4	4-7	4-9	7-8	1-3	27-33

In Table 1 the figures for the period "cocoon to pupation" are placed in brackets because the period shown for the pupal stage includes these, making the actual pupal period shorter. Formerly it was thought that pupation succeeded the completion of the cocoon almost immediately, but more accurate records show that this is not the case. The total period from the formation of the cocoon to the emergence of the moth proved, however, to be much shorter during the outbreak at Kuala Dipang than in other localities. Previously a period of eight to ten days elapsed, but last year this was shortened to from seven to eight days.

In the original paper, when the life-history of *A. catoxantha* was first published, it was stated that owing to the methods which had to be employed the results were probably not very accurate, but had been found sufficiently correct for calculations in the field. In the present paper the previous figures are therefore compared with those obtained in 1925 in Table 2. The later figures show that the total

period is somewhat shorter, but although more accurate, these figures still require further checking.

In order to test the accuracy of the figures obtained in individual breeding cages in the laboratory, records of the various stages were kept on small palms and in the field. In the first case pinnae bearing eggs were placed on small palms growing in tubs in the insectary, and in the second the times at which the various stages were observed in the field were noted. The results are given in Tables 3 and 4. The pupal period in Tables 2 to 4 includes the period "cocoon to pupation".

TABLE II.

Comparison of Life-history figures.

		Previous Figures.		1925 Figures.	
		Range.	Mean.	Range	Mean.
Instar	I	4 - 5	4.6	3 - 6	4.4
Instar	II	4 - 5	4.8	2 - 6	3.4
Instar	III	3 - 5	3.6	3 - 4	3.1
Instar	IV	3 - 4	3.9	4 - 7	4.8
Instar	V	6 - 7	6.7	4 - 9	6.2
Pupa		8 - 10	9.0	7 - 8	7.5
		Total ...	32.6 days.	Total ...	29.4

TABLE 3.

Mass breeding on small palms.

No.	Eggs hatched.	Cocoons formed.	Larval Life.	Emerged	Pupal period.	Total
240	29.7.25	20/8 to 23/8	22-25 days	29/8 to 1/9	7 days.	29-32 days
240	do.	17/8 to 22/8	19-24 „	27/8 to 1/9	10 „	29-34 „

TABLE 4.

Field observations on Life-history.

Adults first collected on ...	22.7.25
Eggs first seen ...	24.7.25—2 days (preoviposition)
Larvae first seen (just hatched) ...	28.7.25—4 days (incubation)
Pupae first seen ...	21.8.25—24 days (larval life)
Adults first seen ...	31.8.25—10 days (pupal period)
Total ...	40 days.

Description of Stages.

Under this heading further notes are given in extension of those previously published. For purposes of control and the study of parasites affecting the larva, it is necessary to be able to distinguish the instar of individual caterpillars. An attempt has been made, therefore, to describe the five larval instars in sufficient detail for this to be done, but even when well acquainted with them by sight it is by no means easy to separate them, owing to the manner in which one instar will show many of the characters of the succeeding instar just before ecdysis occurs.

THE EGG AND ECLOSION.

Viewed under a high power the egg is seen to be minutely tessellated. The chorion is very soft and easily ruptured, and just prior to the emergence of the larva one pole of the egg becomes slightly enlarged. The day before hatching takes place the larva may be seen lying on its side, the mandibles being clearly visible.

Hatching appears to take place at night or in the early morning, but some eggs were observed to hatch in the laboratory in the early afternoon. The larva emerges from the enlarged pole, and eats a portion of the shell as its first meal. Next day it begins excavating the leaf, and the remaining portion of the chorion, which has retained its shape, collapses. Eggs hatched in the laboratory at temperatures between 31°C. and 20°C. At 33°C. only one out of a batch of 12 hatched, and from 18°C. there was a gradual decrease in the number hatching down to 13°C., at which none hatched after remaining at that temperature for a week.

THE LARVA.

Instar I.—(Figure 1) Length 1 mm. Translucent, tinged with pale green, the greenish tint becoming darker as soon as the young larva begins feeding. Almost wedge-shaped, owing to the very large first and second thoracic segments.

Instar II.—(Figure 2) Length 1.5—2 mm. Darker greenish yellow, due to ingested food. The first thoracic is less prominent, the second being the largest segment. Two small orange coloured patches are situated subdorsally on the second thoracic segment where the tufts of hair are situated. In addition to these a suggestion of the markings in the third instar may be seen as follows:—

(*a*) Median orange patch on the 2nd thoracic.

Rare { (*b*) Upper stripe on the 2nd subdorsal tubercle of the 3rd thoracic segment.
(*c*) Streak on the 2nd subdorsal tubercle of the 11th segment.

Instar III.—(Figure 3) Length 4—5 mm. A pair of semi-lunar orange patches between the two tufts of hair on the second thoracic, accompanied by a median fascia of the same colour, the intensity of the colour of the latter becoming less posteriorly. A median purplish-brown fascia on segments three to eleven, extending very faintly into the twelfth. The second (lower) subdorsal row of tubercles on the third segment lined with purple at the base above and below, similarly situated tubercles on the fourth segment being lined above only. A faint streak similarly situated on the eleventh segment.

The dorsal stripe may be brown, the other markings in this case being light brown. It is not always continuous, but may be broken or very narrow. At three days old the markings on the third segment are extended, but still light in colour. The markings on the fourth, eleventh and twelfth segments are also enlarged, and have become darker in colour. Just before moulting the white subdorsal fascia of the fourth instar becomes apparent.

Instar IV.—(Figure 4) Length 5—6 mm. Two orange patches appear on the sides of the head, together with a median band of the same colour. The dorsal fascia is purple, almost black in some cases. Two subdorsal white fasciae are seen extending along the line of the first (upper) subdorsal row of hair-tubercles from the third to the eleventh segment, being present but only faintly marked on the twelfth.

Dorsal purple fascia on the twelfth segment distinct, but separated from the anterior portion. The dorsal fascia is usually made up of separate fasciae on each segment joined by a thin streak on the intersegmental areas.

Hair tubercles on the third segment completely concolourous with the dorsal fascia, the coloured portion extending so as to form a circle round the tubercles, continuous with the dorsal fascia. The coloured patch on the fourth segment is larger and darker in colour, but limited to the space between the upper and lower subdorsal tubercles. Coloured patch on the eleventh segment prominent and concolourous with the dorsal fascia.

The dorsal purple fascia and the two subdorsal white fasciae are situated within a broad band of green, slightly darker than the rest of the body which remains a light translucent green.

Instar V.—(Figure 5) Length 8—10 mm. The whole of the first and second segments are now orange-yellow in colour, including the hair tufts. At the junction of segments four and five two orange or pinkish spots may be seen. Two spots similarly placed are present on the mid-portion of the third segment.

The subdorsal white fasciae are suffused with blue between segments three and four and are divided, there being a narrow white edging to the dorsal purple fascia and a narrower subdorsal fascia situated along the lower row of subdorsal tubercles. Round black spots are present on the hair-tubercles of the eleventh segment.

The dorsal fascia on the twelfth segment is replaced by a patch of colour, sub-trapezoid in shape, the sharper angles of which point forward and backward. Just behind the lateral angles of this patch, situated subdorsally, is a pair of translucent papillae.

PRE-PUPAL PERIOD.

As already stated, a period elapses betwen the completion of the cocoon and pupation. After the cocoon is formed the larva becomes smoother and more grub-like in appearance, loses its characteristic colouring and becomes immobile. The pre-pupal period varied from one to three days, and is shown in Tables 1 and 5. In several instances where the period was three days it was observed that the colouration was lost on the day after the cocoon had been formed, that the larva decreased in size and lost its contours on the next day, and that it pupated on the day following.

CHANGES OF COLOUR IN THE PUPA.

Changes in colour occur after pupation in the eyes, thorax and wings, as shown in Table 5.

TABLE 5.

No. of individuals.	Cocoon formed.	Pupation.	Changes of Colour.							Emerged.	Sex.
			Eyes.			Thorax.		Wings.			
			Red Brown.	Chocolate Brown.	Black.	White.	Dirty White.	Blackish.	Deep Black.		
6	22/8	25/8	26/8	28/8	29/8	29/8	30/8	31/8	1/9	2/9	Male.
8	24/8	26/8	28/8	29/8	30/8	30/8	31/8	1/9	2/9	3/9	,,
2	25/8	27/8	28/8	30/8	31/8	31/8	1/9	2/9	3/9	4/9	,,
1	25/8	27/8	28/8	30/8	31/8	31/8	1/9	2/9	3/9	4/9	Female.

PROPORTION OF SEXES.

The proportion of sexes appears to be equal, but under laboratory conditions rather more males than females reached maturity (227 : 165).

Natural Enemies.

During the outbreak, 17,270 specimens of *Artona catoxantha* in its various stages and of its natural enemies were collected. Although over 2900 eggs were under observation at various times in the laboratory, no parasite on this stage was observed.* Most of the parasites on the larval stage previously recorded were found, but the most common parasites were *Ptychomyia remota* and Braconid No. 1085, in order of importance.

PREDATORS.

During these collections, which were made by cutting off the pinnae and enclosing them, with their insect population, in tin boxes for transport to the laboratory, only 77 specimens of the clerid were taken, and no other predator was observed. From British North Borneo a pentatomid, which was reported to feed on the adult, was forwarded to the writer who provisionally identified it as *Cantheconidea* (*Canthecona* auct.) *furcellata*, Wolff.† This species has previously been recorded as attacking lepidopterous larvae, and when specimens were first received the writer queried the accuracy of the statement about adults. The Assistant Conservator of Forests, B.N.B., confirmed the observation, however, stating that:—"This insect was found to have its proboscis inserted into the body of adults". This would appear to be an unique habit for a member of the Pentatomidae, since although there are many records of these insects feeding on caterpillars and other insects, none has been stated, as far as the writer is aware, to attack an active moth.

Callimerus arcufer, Chpn.‡

The clerid, previously known as *Callimerus* sp. No. 1475, was identified during the year, having been originally described from specimens taken in Penang.

Breeding in captivity was not successful, so that no idea could be formed of the number of larvae of *Artona catoxantha* which are killed during the life of this predator. The larvae were found, however, attacking the pupae of *Ptychomyia remota*, and several older larvae collected in the field were reared entirely on this diet.

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*Mr. Simmonds told me that Dr. Leefmans had found an egg-parasite in Java, but I have as yet no precise information.

†Since confirmed through the kindness of Dr. Guy A. K. Marshall, Imperial Bureau of Entomology.

‡*C. arcufer* was also imported into Fiji and the stock has increased. *See* Dr. Tothill's report abstracted in R.A.E. 14, p. 431.

a

b

c

d

e

PLATE 1.

a. Ptychomyia remota, x 8.
b. Degeeria albiceps, x 6¼.
c. Braconid 1085, x 11.
d. Chalcid 1746, x 12.
e. Callimorus arcufer, x 6.

The pupal period, previously given as ten to twelve days, was found to be actually seven to eight days, the imago remaining in the cocoon for a period of three to four days after eclosion.

THE LARVA.—(Figure 6) Length 8—9 mm. when full grown; slightly flattened. Head well chitinised, dark brown; general colour of body green. On the first thoracic segment are situated two broad, dark brown to black strongly chitinised plates, quadrantal in shape, the centres of the quadrants pointing to the anterior dorsal portion of the tergum; quadrants divided by a thin line on dorsum, the whole forming a rough semicircle. On the second thoracic segment two small, more or less rectangular brown patches are placed subdorsally in the posterior half of the segment; on the third thoracic a blueish dorsal patch, the sides of the segment being black.

Prominent hairy tubercles are situated laterally on all segments from the second thoracic to the eighth abdominal. Body sparsely covered with hair, the tubercles bearing one or more hairs which are longer than those on the rest of the body. Tubercles on the first abdominal blueish; second abdominal similar in colouring to third thoracic. On the third abdominal two narrow black fasciae placed subdorsally. Fourth similar to second, fifth similar to third but middorsum blueish; sixth and seventh similar to second; eighth colourless. Ninth abdominal segment bifurcated, strongly chitinised, black with a narrow colourless band on the anterior portion.

Underside of body green, but the black colouring on the dorsum of the seventh segment extends to the ventral portion.

Legs the same colour as the body but with a yellowish tinge on the tarsi.

THE COCOON.—Length 10—11 mm., breadth 3—6 mm. according to where it is formed. Lightly built in the form of an open network, the majority of meshes being four-sided. There is an inner and outer portion, the inner being more closely "woven". The network is composed of a transparent substance.

PARASITES.

The two species of *Goryphus* and the *Tetrastichus*, previously recorded, were not found during 1925, nor was Chalcidoid 1086.

Four parasites were reared, however, which as far as can be seen have not previously been recorded in Malaya. On the other hand, owing to sexual dimorphism among the Chalcidoidea and other parasitic Hymenoptera, it is impossible

to state with certainty whether a parasite is "new", since it may be merely the other sex of one already recorded. Since it is unlikely that any of them will be identified for some time, however, it is considered best to record them under their respective numbers for future reference. The following notes deal with such data as it was possible to accumulate during the outbreak.

Microgaster sp.—Probably the same as No. 576, already recorded. A parasite of the younger larvae. One specimen only.

Braconid No. 1085. Possibly a species of *Apantales*. This was fairly plentiful, a total of 478 having been reared during the period August 10th to September 13th. Failure was again encountered in breeding this parasite in captivity.

The larva (Figure 7) remains within its host for about ten days. When ready to emerge from its host it is 3.5 mm. in length excluding the anal vesicle and has thirteen indistinct segments; it is smooth, round and curved slightly towards the ventral surface. The thickest portion of the body is at about the eighth segment (0.8 mm.). A prominent anal vesicle is present. Figure 7 shows an outline sketch of this stage, but the head is retracted into the body owing to killing. When the larva emerges from its host the anal vesicle is much reduced and when the cocoon has been spun the head and four or five segments are bent down ventrally.

The cocoon is spun on the same day as the larva emerges from its host, which is still capable of movement but dies after some hours without, as a rule, moving from its position. The pupal period is four to five days.

The majority of adults emerged in the laboratory between 2 p.m. and 3 p.m. Great difficulty was experienced in keeping them alive in captivity, the majority dying in two days when offered sugar syrup as food. A few, however, were kept alive for eight days. On a diet of honey the longevity was slightly increased, it being possible to keep them alive for six to nine days.

Twelve per cent of the last-stage larvae and pupae were attacked by hyperparasites, Chalcidoids Nos. 2656, 1089 A., 2665, 2745 and 1089 B, in order of importance, being responsible.

Chalcidoid No. 2656.—The larvae of this hyperparasite emerge from the larva of the braconid after it has completed its cocoon and just before it pupates. The larva (Figure 8) is 1.5 mm. long and prominently segmented, there being twelve visible segments. The head is broad and flattened anteriorly, 0.5 mm. in diameter, the body tapering to the

anal segment and being curved ventrally; it is slightly flattened laterally. Pupation takes place about three days after the larvae have emerged from their host, the pupal period being about four days. As many as ten have been reared from a single braconid larva, the average number being five.

Chalcidoid No. 1089 B.—This is probably an ectoparasite. One specimen was received from the field, the pupa lying underneath the shrunken larva of its host. The larva appeared to be in its third instar.

Ptychomyia remota.—This was by far the most important parasite, and the data accumulated with regard to it are given in the succeeding paper.

Degeeria albiceps, Macq.* A few specimens of this parasite, previously recorded as Tachinids Nos. 1574 and 1685, were obtained. This is apparently the dominant parasite of *Artona catoxantha* in Java, but it only takes a small part in control in this country. It is easily distinguishable from *Ptychomyia remota*, and the male has smoky wings. The puparium differs considerably from that of P. *remota*:—There is no elevation just below and forming a triangle with the stigmal plates, and the latter are provided with four instead of three slits. The puparium is also partially enveloped in the last larval skin. The life-history has not been worked out in detail, but it is rather longer than that of *Ptychomyia remota*.

Previously Unrecorded Parasites.

Ichneumonid No. 2715.—Two specimens were obtained, possibly a species of *Mesostenos*. An ectoparasite of the pupa; the thin, papyraceous cocoon, about 12mm. in length, being spun under the cocoon of its host.

It is possible that this parasite is also present in Java, since it is similar to the figure and description of a *Mesostenos* sp., given by Dr. Roepke in "Mededeeling van het Proefstation Midden—Java," No. 5, page 19, which has been reared from *Artona catoxantha* and *Acrocercops cramerella*, Sn.

Chalcidoid No. 2669.—The pupa of this parasite was found under a third instar larva (Figure 9). Probably an ectoparasite. It is not included in Figure 10.

Proctotrypid No. 2735.—One specimen, the pupa being found under the cocoon of its host.

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*The writer is indebted to Professor Dr. Mario Bezzi, of Turin, for this identification.

Proctotrypid No. 2736.—One specimen obtained. Pupation took place under the cocoon on the dorsal surface of the host's pupa.

Percentage Parasitization.

During the period August 10th to September 13th careful records were kept of all the parasites found, the total numbers of the pest and its various parasites and the percentage parasitization by the two important parasites being shown in Table 7. The figure headed "others" represents larvae or pupae killed by parasites other than the tachinid or the braconid, by the entomophagous fungus and those which died from unknown causes.

After the moths had emerged, a census of cocoons was taken in order to obtain an idea of the total parasitization at the end of one generation. Daily collections were made from October 30th to November 10th, the results being shown in Table 8. Cocoons containing healthy pupal cases, from which the moths had emerged, were easily differentiated from the cocoons which contained the puparia of *Ptychomyia remota*, and the fact that the cocoons of Braconid No. 1085 adhere to the leaf made it fairly easy to count the number of larvae killed by it. Dead or mouldy pupae were counted separately. In the case of other parasites the difficulty of determining which one was responsible for the death of the pupa precluded them from being distinguished separately, so they were included in the "dead or mouldy". In any case, the percentage of parasitization by parasites other than the principal tachinid and braconid was negligible. An estimate of the percentage parasitization based on the figures is given in Table 9.

Table 7.

Collections from August 10th to September 13th.

—	Total.	Healthy *A. cervantha.*	Parasitized.		
			P. remoti	Braconid. 1085.	Others.
Individuals collected -	10,853	5,837	4,011	473	532
Percentage parasitization	46%	53%	37%	4%	5%

TABLE 8.

Parasitization of One Generation.

Date collected.	Total.	Healthy Pupae.	Parasitized		Dead or Mouldy.
			By *P. remota*	By Braconid 1085.	
30.10.25	617	323	247	41	6
31.10.25	585	194	368	11	12
1.11.25	638	264	309	63	2
3.11.25	628	236	298	87	7
4.11.25	514	236	267	8	3
5.11.25	599	344	247	5	3
6.11.25	913	424	453	31	5
7.11.25	537	269	261	3	4
8.11.25	424	242	168	2	12
9.11.25	457	193	252	5	7
10.11.25	284	167	113	4	...
Totals.	6196	2892	2933	260	61

TABLE 9.

Estimate of Percentage Parasitization based on Table 8.

Ptychomyia remota	...	48%
Braconid 1085 (? *Apantales*)	...	5%
Others	about	1%

The figures throughout these tables will be slightly low for Braconid No. 1085, since a certain number of its cocoons must become detached from the leaf. This has been allowed for in Table 9 by adding 1%, but in Table 7 the actual figure is given because the records during this period are of parasitized caterpillars from which the braconid was reared in the laboratory. In addition, some records would be lost owing to the collection of early instar caterpillars, which, if they

had not been taken from the field, would undoubtedly have been parasitized later. Similarly in the case of *Ptychomyia remota*, the figure in Table 7 would be low owing to the number of caterpillars collected which would have become parasitized later on, and this would affect the figure more than in the case of the braconid owing to the later instars on which *P. remota* lays its eggs, thus allowing a larger proportion of caterpillars to be collected in the time before they could have been parasitized. In Table 9 the figure for "Others", is too low, owing to the fact that large numbers of caterpillars never reach the cocoon stage when attacked by fungous diseases and some of the other parasites. The figures for "Others" shown in Table 7 are probably more representative, although probably somewhat on the high side owing to deaths caused by unsuitable conditions in transit. The figure of 48% for *Ptychomyia remota* in Table 9 is as accurate as any in view of the ease with which the puparia can be counted, and represents a fair average of the extent to which this parasite can attack its host in the presence of hyperparasites.

Inter-relations of Parasites.

In Figure 10 an attempt has been made to show graphically the inter-relations and relative importance of the parasites and hyperparasites of *Artona catoxantha*.

Without being an expert in the classification of the parasitic Hymenoptera, and in the almost total absence of any literature on the Chalcidoidea and other groups, it is well-nigh impossible definitely to decide whether a parasite reared in the laboratory is a different species or merely another specimen of a species already recorded. An attempt has been made, however, roughly to separate the numerous specimens obtained, and the results are shown in Figure 10. When the collection is finally identified more complexities will undoubtedly be found, but for the present a very conservative opinion is given. Of the parasites, *Ptychomyia remota* is by far the most important, and although it will breed on other caterpillars it is a primary parasite of *A. catoxantha* and more or less limited to it as far as our present records of Tachinidae show, it never having been bred from any other insect in Malaya except experimentally in the laboratory. It is attacked by a predator and twelve hyperparasites.

Braconid No. 1085 comes next in importance, and is probably much more potent as a controlling agent in "non-outbreak" times than appears during outbreaks. Moreover, although there is a certain amount of competition between it and *Ptychomyia remota*, it usually attacks the younger instars, providing an excellent sequence in parasitization. It is itself attacked by five hyperparasites. *Callimerus arcufer* is fairly important as a controlling agent, but unfortunately

is more catholic in its tastes than the two principal parasites and attacks the pupae of *Ptychomyia remota*. In addition it will kill caterpillars already parasitized by the tachinid or braconid.

Chalcidoid 1089 A, has been found as a parasite of *Artona catoxantha*, but also as a hyperparasite attacking both *Ptychomyia remota* and Braconid 1085. Similarly, Chalcidoid 1089 B has been found attacking the braconid as well as the caterpillars of the moth. Chalcidoid 1746 attacks *Artona catoxantha*, but has also been reared from *Ptychomyia remota*.

Of the hyperparasites, Chalcid 1594 is by far the most important, and is a serious enemy of *Ptychomyia remota*. A preliminary account of this rather interesting insect is published in the present issue of this journal. Next in importance are Chalcidoids 1497 and 2656 on the tachinid and braconid respectively.

Others are of minor importance as far as is known at present, but much more study is required before hard and fast figures can be given. As an instance of the danger of assuming that because a parasite is bred from a pest it is therefore directly beneficial in controlling it, the above records, as far as they go, are interesting. To give one instance only, Chalcidoid 1746 is more often found as a hyperparasite on *Ptychomyia remota* than as a parasite on *A. catoxantha*, and is therefore a harmful insect from the point of view of control. Superparasitism was prevalent to a large extent in the Kuala Dipang outbreak, both on the part of *Ptychomyia remota* and of the latter and Braconid 1085. In the case of *Ptychomyia remota* the deposition of more than one egg on a caterpillar did not result in the death of host and parasite. Although numerous larvae could be found by dissection in these caterpillars, one always became dominant and reached maturity, the only effect of the superparasitism being that a large number of potential parasites in the next generation was killed. Competition between the braconid and the tachinid, however, was attended with more serious results, but no exact data are available.

In many outbreaks of *Artona catoxantha* the terminating factor appears to be weather conditions rather than the parasites, which do not go beyond a certain point. In the 1925 outbreak at Kuala Dipang it was very noticeable, as will be seen from Tables 7 and 8, that a considerable number of larvae escaped, thus allowing large numbers of moths to emerge and start a new generation of considerable proportions. Before it was possible to start collections for accurate records, it was noticed that at the end of June the older caterpillars were heavily parasitized by *Ptychomyia remota*, but that younger caterpillars, which remained healthy, carried on the generation comparatively slightly affected by parasites.

It has been noted that the urge to oviposit is well marked in *Ptychomyia remota*, irrespective of whether the resulting larva will be able to complete its metamorphosis or not. Hence if only young caterpillars are available and the fly lays its eggs on them the youngest will be wiped out. From observations made on eggs which were laid on second and young third instar caterpillars it was found that in the majority of cases there was not enough nutriment in the small caterpillars for the maggot to complete its development, and both died. That such a habit is abnormal, however, stands to reason, for if this were the case the fly would rapidly extinguish itself, and it is known that the normal habit of the fly is to wait until caterpillars of suitable size are available.

In the field a certain amount of time elapses between the maturation of the caterpillars produced by the earliest and latest-laid eggs, and should there be any considerable lapse of time between the first and last eggs laid by the moth the fly will oviposit on the caterpillars which first attain a size suitable to the development of the maggot. Should the fly lay all its eggs on these earlier maturing caterpillars, the later caterpillars will escape.

There are one or two further considerations which it is perhaps advisable to mention in this connection. Firstly, the outbreak at Kuala Dipang was different from those previously observed in two directions. There was a much larger number of parasites in evidence than is usual in the early stages of an outbreak, and the parasites were attacked by hyperparasites to a degree hitherto unrecorded. Secondly, it is the writer's belief that the Kuala Dipang outbreak was not a simple one, that is, it was the result of two separate foci of outbreak, separated by a slight interval of time. This resulted in a community of larvae of ages differing more widely than is usual. The flies emerging from the pre-pupal larvae of one generation found larvae of another generation which were almost ready for oviposition, and the slight difference caused a break in the normal sequence resulting in many eggs being laid on young caterpillars.

On the other hand, since the caterpillars of one generation take slightly varying times to reach the cocoon stage, *Ptychomyia remota* will also take varying times to reach maturity, since its rate of development is dependent upon its host. Thus from August 14th to 21st, fifth instar caterpillars parasitized by *Ptychomyia* were brought into the laboratory, giving adult flies continuously from August 23rd to 30th. Now as the flies emerged they would attack caterpillars of suitable age, thus securing a sequence of attack on caterpillars of varying ages for seven days. What then, was the cause of the younger caterpillars remaining unattacked?. The writer's opinion is that this gap was entirely due to the hyperparasites, all of which attack the pupal stage of the

parasite. In the case of Hyperparasite 1594, oviposition will continue for a period of over ten days, or beyond the pupal period of the parasite, so that secondary parasitism by this insect will be cumulative and affect the later-emerging flies most heavily. Hence the flies which emerged first attacked caterpillars of suitable age, but those which should have come a few days later, to attack the caterpillars which had by then attained the correct size, never emerged at all but were killed by hyperparasites.

If reference is made to the chart of percentage parasitization accompanying the paper on *Ptychomyia remota* (Fig. 9) it will be seen that there is a gradual increase in the number of parasitized *Artona* day by day, but that the hyperparasites of *Ptychomyia* increase rapidly towards the end of the period until on the last three days they are present in practically every pupa collected. Thus it is the later pupae of the parasite which are affected most seriously, there being a considerable number of flies emerging from about September 6th to 11th from pupae derived from the heavily parasitized *Artona* from August 29th to September 2nd. In actual numbers 1077 pupae of *Ptychomyia* were collected from August 29th to September 2nd, of which 264 were parasitized, and from which 813 flies emerged. From September 8th to 13th, however, out of 729 pupae collected only 164 flies emerged.

It would therefore appear that a gap in the sequence of emergence of the parasite is created by the hyperparasites, and hence a gap in parasitized *Artona* larvae will be formed in the succeeding generation.

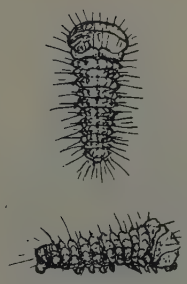


FIG. 1

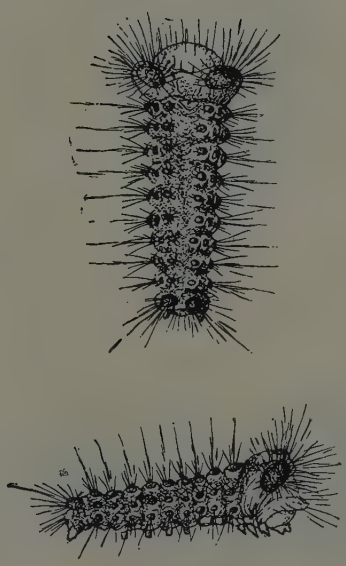


FIG. 2

LARVA OF ARTONA CATOXANTHA.

Fig. 1. First instar x 20.
Fig. 2. Second instar x 20.

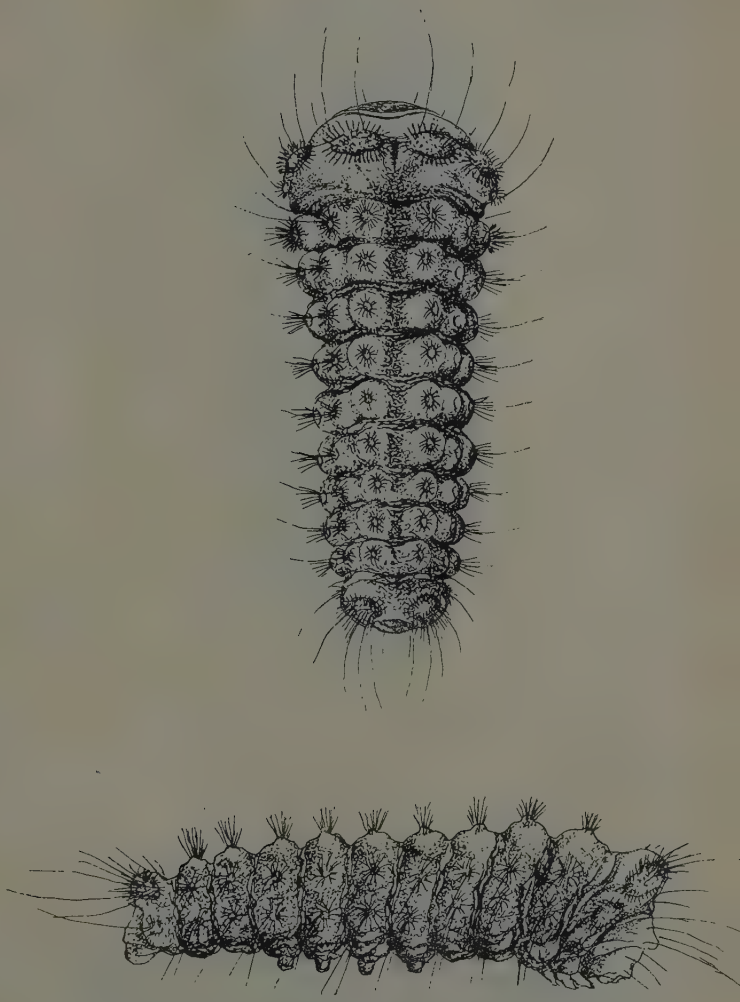


FIG. 3

LARVA OF ARTONA CATOXANTHA.
Third instar x 20.

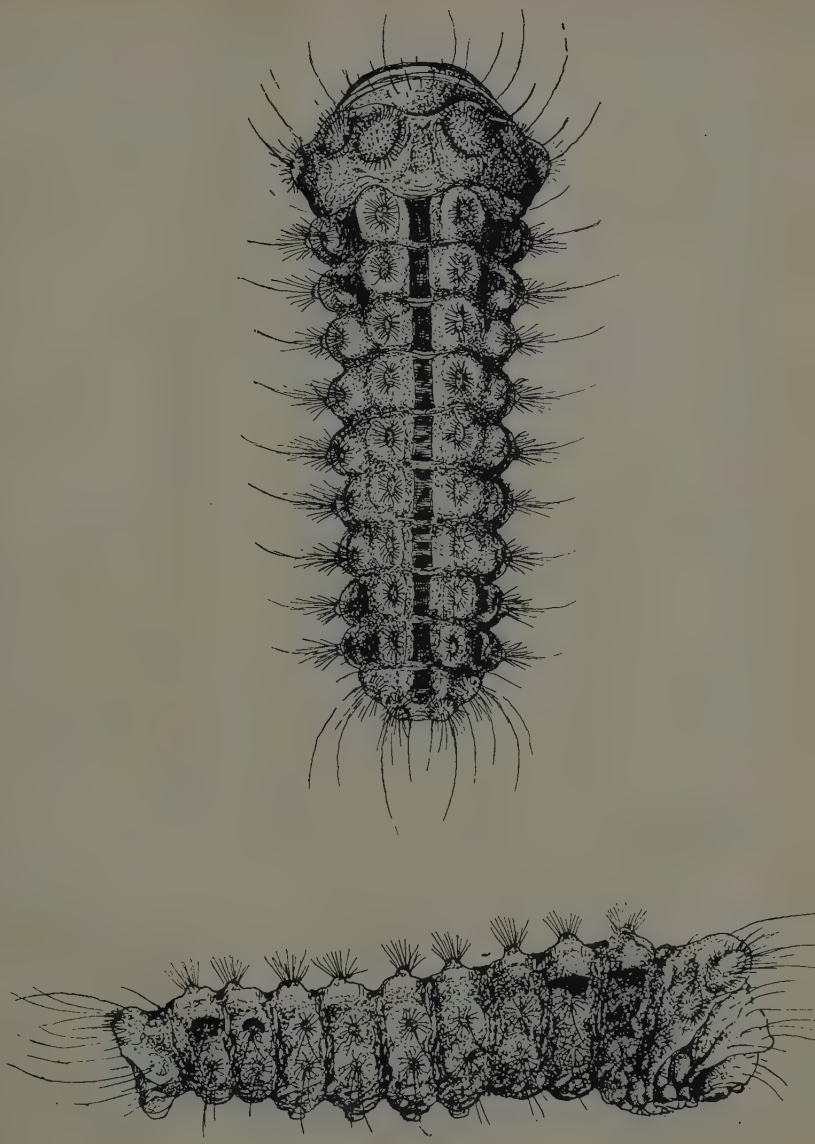


FIG. 4

LARVA OF ARTONA CATOXANTHA.

Fourth instar x 16.

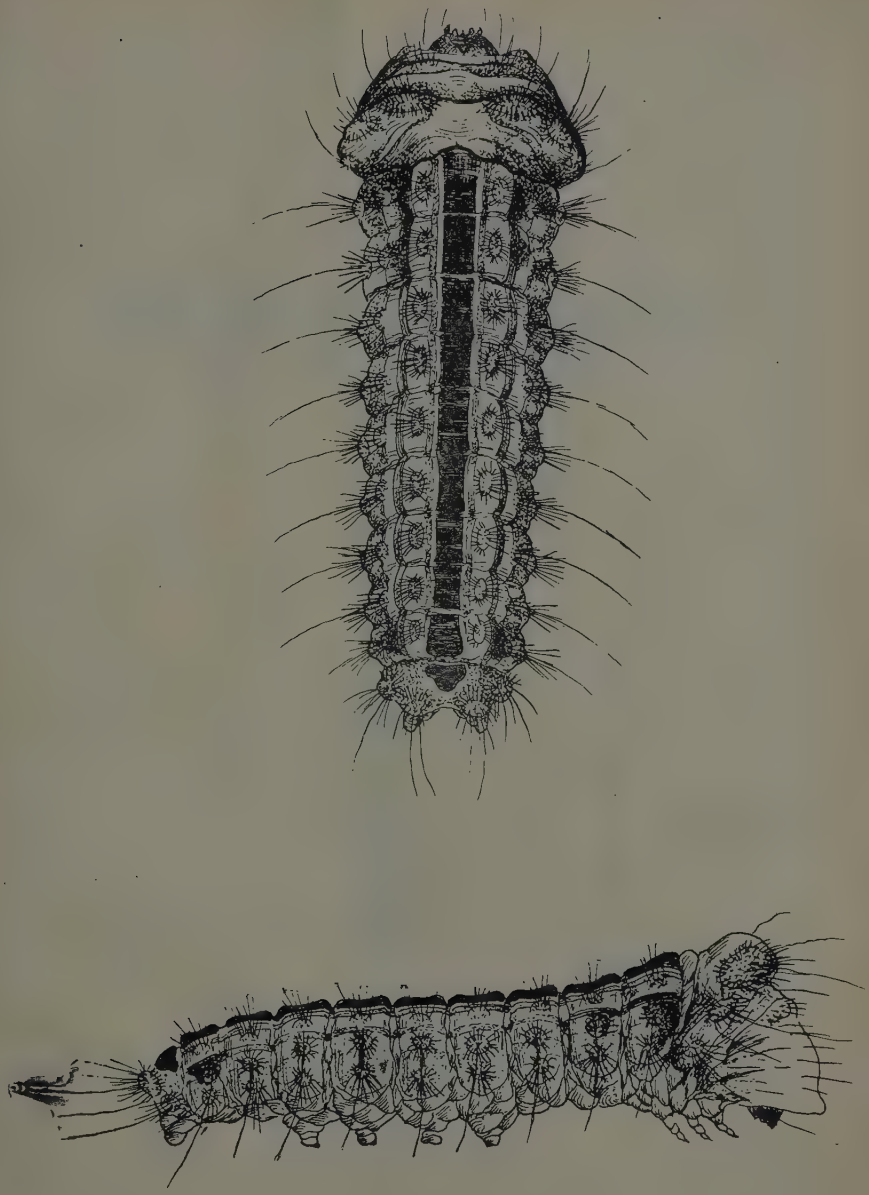


FIG. 5

LARVA OF ARTONA CATOXANTHA.

Fifth instar x 12.

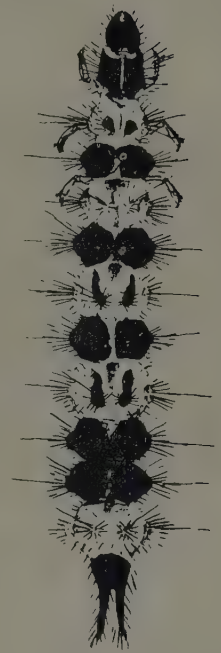
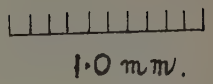


FIG. 6

LARVA OF CALLIMERUS ARCUFER x 12.

FIG. 7

FIG. 8



Larvae of Braconid 1085 (fig 7) and Chalcid 2656 (Fig 8).

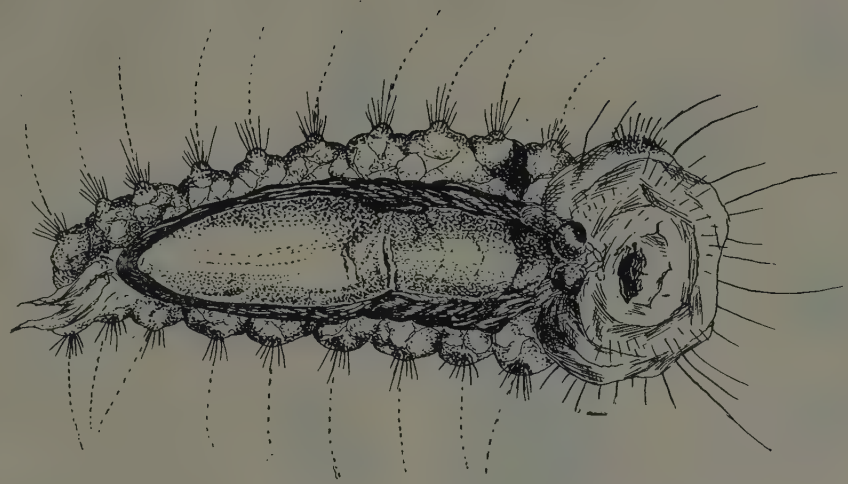


FIG. 9

PUPA OF CHALCID 2669 ON HOST LARVA x 32

FIGURE 10
THE "ARTONA COMPLEX"

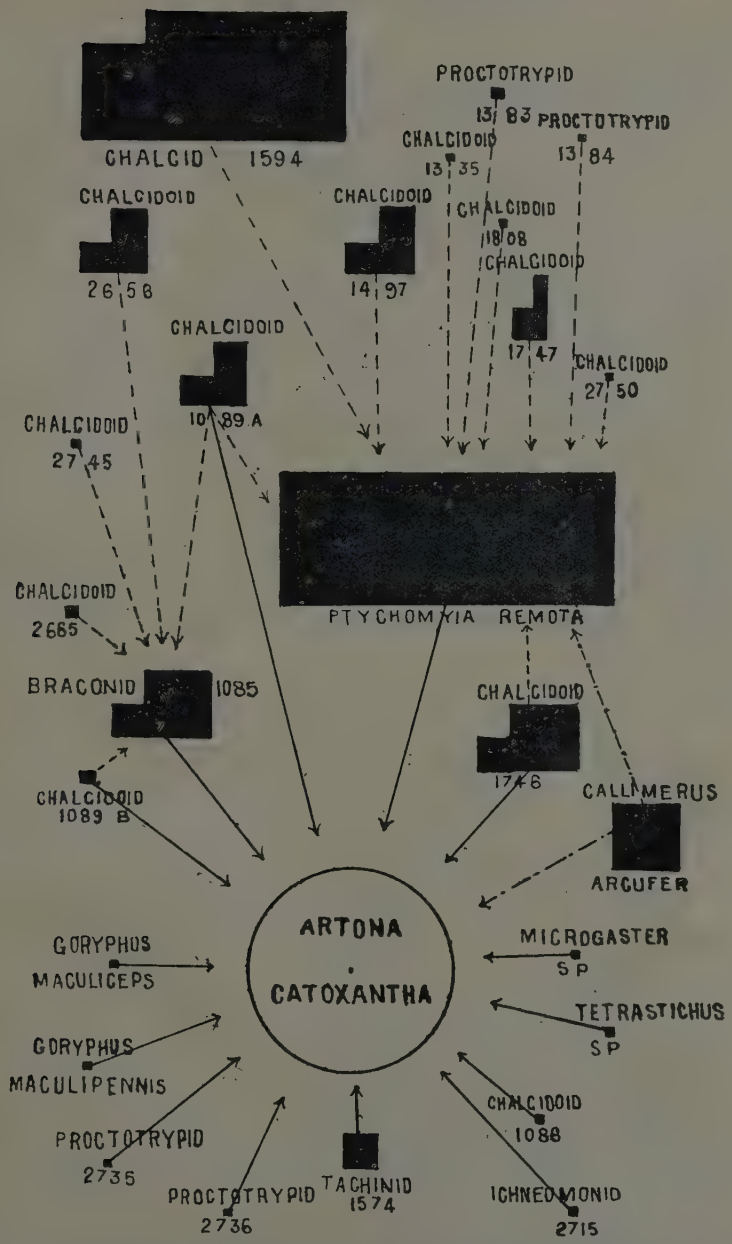


DIAGRAM SHOWING THE INTER-RELATIONS AND RELATIVE IMPORTANCE OF THE PARASITES AND HYPERPARASITE OF A. CATOXANTHA

——— : PARASITE ; - - - - - - HYPERPARASITE — — — — PREDATOR

FURTHER REMARKS ON *PTYCHOMYIA REMOTA*, ALD., A PARASITE OF *ARTONA CATOXANTHA*. HAMPS.

B. A. R. Gater.

Introduction.

In an earlier issue of this Journal* a preliminary account was given of a tachinid, *Ptychomyia remota*, Ald., which was considered to be the most important of the known parasites of the Malaysian Coconut Zygaenid, *Artona catoxantha*, Hamps. During the 1925 outbreak of the latter, this parasite was studied in more detail in some of its phases, and owing to its importance not only in this country, but in Fiji, whither it was taken during that period, it is thought that the results of the later investigations, as far as they go, should be published.

The conditions under which the outbreak of *Artona catoxantha* took place last year were not entirely normal, and several points in the life-history of the parasites differed from those previously observed. The high degree of hyperparasitism and the inability of the parasites to get beyond a certain point in the control of their host were especially noticeable.

Perhaps the most vitally important result of the investigations carried out in this laboratory on this insect was its successful importation into Fiji, where it is reported to be readily attacking the zygaenid, *Levuana iridescens*, Beth. Baker, and will no doubt be a most important factor in the ultimate control of that most serious coconut pest. Time only will show to what extent it will be able to control the Fijian insect, but preliminary reports are so promising that it would seem as if the first utilization of a Malayan parasite were to be attended with very great success.

History.

Artona catoxantha has been known to the Malays as a pest of coconuts for generations, but the first published account of it, as far as the writer has been able to ascertain, was by Ridley in 1904, when he described the then unidentified insect as being a serious pest. It was not until 1914, however, that any actual mention was made of a tachinid parasite, in Burkill's report for that year. Pratt, in his bulletin on *Artona catoxantha*, mentions that about twenty per cent of the caterpillars of the third brood were parasitized, but does not describe any of the parasites. It is probable,

*"Some observations on the Malaysian Coconut Zygaenid (*Artona catoxantha*, Hamps.)" M.A.J., Vol. 13, page 92, April, 1925.

however, that his remarks refer to the tachinid. Previously, in his report for 1906, he makes no mention of any parasites, and merely presumes that the failure of an egg-parasite was the cause of outbreaks of the caterpillars. A tachinid parasite appears to have been first mentioned in Java by Keuchenius in 1916, but it is possible that this was not *Ptychomyia remota*, but another, which takes precedence in importance in Java, and has been recently identified as *Degeeria albiceps*. The latter also occurs in Malaya, but the position is reversed, it being only found occasionally. Attempts were made in this laboratory to rear the parasites of *Artona catoxantha* in 1920, but without success. In 1923 the writer first saw an outbreak of *catoxantha*, and an examination of the material at Batu Gajah, and rough counts of the puparia found under the moths' cocoons, revealed the importance of *P. remota* as a parasite. The following year brought several outbreaks, and the pest and its parasites were studied in more detail. The tachinid was named during 1924 by Dr. J. M. Aldrich, from material which had been bred out during the course of the investigations.

INTRODUCTION INTO FIJI.

In October 1920 a letter was received by this department from Mr. C. H. Knowles, Superintendent of Agriculture, Fiji, asking for information about the parasites of *Artona catoxantha*, especially the hymenopterous parasites, with a view to importing them for the control of *Leruana iridescens*. So little was known at that time, however, that no information could be given beyond what had already been published, but some cultures of the fungous parasite were forwarded, since it was then considered that the latter was the most important factor in control.

January 1923 brought a letter from the Government Entomologist, Fiji, written in the previous December, asking for information. Again little was forthcoming, but an offer of assistance was given. Mr. H. W. Simmonds wrote again in March 1923, reporting the failure of the fungus and intimating that he would like to try and introduce the braconid. This was received about the time of the outbreak of *catoxantha* of Batu Gajah which was visited by the writer, and in reply to Mr. Simmonds the Government Entomologist, F.M.S., Mr. G. H. Corbett, stated that a tachinid was greatly in evidence as a parasite and suggested that it might be possible to transport the pupae of the latter in cold storage.

At the end of 1923 Mr. A. Despeissis, then Acting Superintendent of Agriculture, Fiji, forwarded another appeal for help, but little information was forthcoming from this end. In the early part of 1924 Mr. Despeissis wrote again, and this time it was possible for Mr. Corbett to inform him that the writer was working on the bionomics of *catoxantha* and that every endeavour would be made to help. In

August 1924 it was possible to report that the tachinid was the most important parasite and that it had been found possible to breed it on caterpillars other than those of *Artona catoxantha*, thus showing that it would in all probability attack the nearly related *Levuana iridescens*. The writer's paper on *Artona catoxantha* was then in preparation, and in August he took a consignment of *Ptychomyia remota* to the island Pulo Kuraman, near Labuan, where an outbreak of the pest was in progress. In view of the short journey of only five days this was a simple matter, but it was actually the first instance of the importation of *Ptychomyia remota* into a district from which it was previously absent. Meanwhile the life-history and some details about the hyperparasites had been worked out. The writer's letter of August 1924 was transmitted to Mr. A. M. Lea of the Adelaide Museum, who had meanwhile been commissionned to study the original habitat of *Levuana* and to confer with the writer on the best means of transporting parasitized material to Fiji. On Mr. Lea's arrival in Kuala Lumpur the writer placed all the information available at his disposal, and strongly urged the value of *Ptychomyia remota*. The difficulty was that the short life-history, and the reluctance of *catoxantha* larvae to live well in small cages, precluded the possibility of a simple transportation owing to the time taken on the journey to Fiji. The writer had already found that the ordinary cold storage temperatures killed the pupae. Unfortunately for Mr. Lea, he arrived in this country just as the last outbreaks of *Artona catoxantha*, of which there had been several that year, had completely died out, and he was unable to obtain any material. His idea was to try and transport the pupae either by aeroplane or by means of a T. B. Destroyer which could make the direct journey in a short time. Both these means of transport presented considerable difficulties, but Mr. Lea thought that if the journey by air could not be managed the alternative would be to take living palms with the parasitized caterpillars on them.

Towards the end of the year it became evident that, as far as our knowledge of *Artona catoxantha* went, there would be no further outbreaks until at least the following March. There was, however, an outbreak in Java, and Mr. Lea went there with the intention of obtaining material. He took a shipment of tachinid pupae on ice in the early part of 1925, but all died on the way. It is probable that the tachinid shipped from Java was not *Ptychomyia remota*, but the other parasite, *Degeeria albiceps*. Shortly afterwards Messrs. H. W. Simmonds and C. H. H. Taylor arrived in Kuala Lumpur, and meanwhile Dr. J. D. Tothill had taken over the organization of the "Levuana Campaign" in Fiji. It was Dr. Tothill's intention, if possible, to take parasitized larvae to Fiji in specially constructed cages, and with our knowledge of the life-history of *remota* it was agreed that this was possible if an accelerated route could be arranged, although somewhat expensive. After waiting three months, material

became available, and large cages were made which would accommodate small growing palms. After some difficulty the Government of Fiji arranged for the "Clan Mackay" to call at Singapore on July 4th, 1925. The "Clan Mackay", however, was delayed owing to having to go to the assistance of another ship, and it appeared as if the first attempt were going to fail. Arrangements were finally made, however, for the "Clan Matheson" to sail direct from Java to Suva, Fiji, and for the cargo of parasitized material to be transhipped from the "Clan Mackay" at Surabaya. Superhuman efforts were made by Messrs. Simmonds and Taylor, assisted by a staff of native collectors, to obtain enough material in time for shipment, and eventually the cages, occupying about 1000 cubic feet of cargo space were loaded on the night of the 12th July at Surabaya. During the transference of the material from the outbreak near Batu Gajah to Singapore, the Federated Malay States Railways rendered invaluable assistance.

On the 3rd of August the cargo arrived at Suva, and it was found that some 300 adult *Ptychomyia remota* were still alive, and they immediately laid eggs on *Levuana* larvae. Writing on November 3rd, Dr. Tothill stated:—

"The Tachinid *Ptychomyia* is doing very well on *Levuana*, and we are now breeding out in the insectary about 700 a week, and have fortunately, overcome the difficulty of rearing in captivity, which we met with at first. One colony is already well established and the flies have laid about half a mile in all directions from the point of liberation. At the actual point of liberation the percentage of parasitism was well over 70% about two weeks ago. Now, however, it is less as the present lot of last stage *Levuana* evidently does not happen to coincide with a wave of laying flies.

"However, I do not expect any large percentage until thorough diffusion of the species has taken place. As a matter of fact, the species was taken hold more quickly than any Tachinid I have had experience with, or knowledge of, as many of those that were introduced into the United States, on the Brown Tail and Gipsey moths, would be lost to sight for periods up to 5 years, which would represent the period of diffusion."

Since then the latest reports show that by November 23rd over 12,000 parasitized larvae had been obtained, most of which have been liberated.* The greatest praise is due to Dr. Tothill and his co-workers for the initiative and energy with which the transport and breeding of the parasites was undertaken, and the conclusions arrived at as to the value of *Ptychomyia remota* in this country in August 1924 appear to have been fully justified.

**See* Dr. Tothill's reports abstracted in R.A.E. 14, p. 431:—
"This fly is now definitely established and is parasitising up to 75 per cent of the moth", and "A rate of parasitism of 75 per cent is commonly attained, 80 and 85 per cent is not rare, and 90 per cent is occasionally reached".

According to the mean times for the various stages of the development of the fly, worked out in this laboratory, the time during which it could be transported in its immature stages was only twenty days, viz:—Egg two days, larva nine days and pupa nine days. Added to this, the mean adult life was ten days, making thirty days in all. The time taken to transport the flies to Fiji was twenty-six days, there being only a margin of four days. The adult life can, however, be much longer than the above, which was worked out in small cages, and as pointed out in the previous paper in nature it must be nearer twenty days. The fact that only a small percentage of larvae with newly laid eggs could be collected, and that it was uncertain how long the adults would survive in the cages in the absence of caterpillars on which to lay eggs, caused considerable anxiety as to whether any would survive the journey. The result, however, in obtaining a batch of three hundred adults from the shipment, was most gratifying.

Later experiments on the resistance of the pupae of *Ptychomyia remota* to low temperatures, which were being carried on in this laboratory during this period, seem to show that it would have been possible to ship the pupae in a cool chamber, which would have been a matter of much less difficulty and expense, and should the preliminary results be confirmed this method will no doubt be used on any future occasion. The discussion of this aspect of the problem will be found under its own heading.

Description of Stages.

THE LARVA.—(Figures 1 to 4). A primary sheath is formed by means of which the larva maintains connection with the air throughout its existence, the funnel being well chitinised and resulting from an ingrowth of the integument following on the puncture caused by the entry of the first-stage larva. During the last stage or third(?) instar the sheath is ruptured and the larva devours the tissues of its host, emerging from the emptied caterpillar.

The last-stage larva is 5 to 7 mm. in length and about 2 mm. in diameter at its greatest thickness, which is about the sixth or seventh segment. It is broadly cylindrical with twelve visible segments easily differentiated, tapering slightly towards the anterior portion of the body. Head small, mandibular sclerites prominent; cephalo-pharyngeal skeleton well developed (Figure 3). Posterior spiracles prominent, dark, heavily chitinised, placed just above the longitudinal axis of the body and separated by about half their own width; the stigmal plates (Figure 4) are very slightly raised above the level of the segment and are provided with three slits opening from narrow ridges.

If the integument is closely examined a band of minute spinules may be seen on the anterior portion of each segment.

THE PUPARIUM.—(Figure 5). Length 4.5 mm. to 5.0 mm.; in exceptional cases the length may be only 2.5 mm. Medium to dark brown, subshining, smooth, almost regularly cylindrical but inclined to taper slightly towards anal end; segmentation fairly distinct, marked by narrow bands of minute spinules at sutures. Stigmal plates (Figure 5b) shining black, slightly rugose, showing contours of ridges, slightly raised, placed just above longitudinal axis and separated by about half their own width. Slits three in number; button round, small and slightly below level of slits. On the longitudinal axis below stigmal plates, almost contiguous and forming a triangle with them, is a rounded tubercle with a crater-like depression. Anal opening located far below.

THE ADULT.—The imago was described by Dr. J. M. Aldrich, and since the Proceedings of the Entomological Society of Washington are not available in this country, his original description is here reprinted:—

"Resembles *Ptychomyia selecta* Meigen, type of the genus, in size and the following characters (I have only the female of *selecta*, one European specimen determined by Brauer and Bergenstamm, for comparison): eyes and parafacials bare; ocellar bristles proclinate, far apart, located a trifle below the level of the anterior ocellus; third antennal joint long, nearly five times the second in the female, penultimate joint of arista about three times as long as thick; facial ridges with strong erect bristles almost up to arista; facial depression deep; bucca (below eye) narrow. Third vein with strong setules at base, usually extending nearly to the crossvein. Four dorsocentrals, three sternopleurals; mid tibia with two bristles on outer front side, the upper one smaller; hind tibia with irregular row on outer extensor side; female with last abdominal segment in the form of a short, blunt cone.

"Differs from *selecta* in having yellow palpi, a pair of small apical scutellars directed backward besides the three lateral ones; no discal abdominal macrochaetae.

"Color black, except palpi. Front in both sexes .31 of the head-width (two males and two females all measured the same by micrometer); parafrontals, mesonotum and basal half of abdominal segments 2-4 with golden-yellow pollen; parafacials silvery, at narrowest less than half as wide as third antennal joint; bucca hardly one-tenth of eye height; frontal bristles rather far apart, only about seven in number, the lowest almost meeting the row on facial ridge. Apical half or more of abdominal segments 2-4 shining black, the basal pollinose bands interrupted in middle.

"Length 4.5 to 5 mm.

"*Type.* Male, Cat. No. 27,739, U.S.N.M."

(Reprinted from the Proceedings of the Entomological Society of Washington, Vol. 27, No. 1, January, 1925).

Life History.

The times taken for the development of the various stages were checked and found comparable with those previously given.

Egg-laying.—The instinct to oviposit appears to be particularly strong in this insect, and if larvae of its normal host are not present it will lay eggs on almost any larva offered. During the "longevity of adults" experiments it was noticed that a number of eggs was laid on dead flies at the bottom of the cage. In one cage 104 eggs were laid in this manner, as many as 27 being found on one dead fly. The eggs failed to hatch in all the cases examined.

Larval period.—In cases where caterpillars of the fifth instar are supplied to flies in captivity a few days only before they are due to pupate, it appears that the larval period can be accelerated, the period from the deposition of the egg to the emergence of the larva for pupation being reduced to four days, as is shown in Table I. In all cases where this was observed, a dwarfed adult was produced.

Table I.

Accelerated Larval Period.

Adult emerged 31.9.25, died 20.10.25; fed on honey.

Caterpillar supplied	9.10	9.10	10.10	10.10	10.10	10.10	11.10	11.10
Eggs laid -	11.10	10.10	10.10	10.10	10.10	10.10	11.10	11.10
Cocoon formed -	11.10	11.10	11.10	12.10	12.10	12.10	12.10	12.10
Caterpillar died -	12.10	13.10	13.10	13.10	14.10	14.10	14.10	14.10
Larva emerged -	14.10	14.10	14.10	15.10	15.10	15.10	14.10	14.10
Pupated -	14.10	14.10	14.10	15.10	15.10	15.10	15.10	15.10
Adult emerged -	23.10	23.10	23.10	23.10	23.10	23.10	23.10	23.10

Emergence of larva.—Records were taken of the period which elapses between the spinning of the cocoon by the host

and the emergence of the larva of the parasite before pupation. The period was found to vary between one and four days, but most usually occurred on the second day following the completion of the cocoon. Pupation occurred on the same day as emergence from the dead caterpillar.

Pupal period.—During the 1925 outbreak the pupal period was usually a day or so shorter than had been observed on previous occasions, varying from six to nine days with a mean of eight days.

Proportion of sexes.—This has not been worked out under field conditions, but in the laboratory rather more females than males emerged. One batch giving 186 individuals was examined and 102 females and 84 males were counted, giving a proportion of roughly 5:4.

Longevity of adults.—Throughout the previous experiments with *Ptychomyia remota* great difficulty was experienced in keeping the flies alive in captivity for any length of time. Last year the effect of various foods on longevity was tried.

In the first series of experiments simple food substances were made up in solution, starch, albumen and cane sugar being used as well as a 'composite' food containing all three. Large glass jars were used as cages, and the food solution was placed either in a tube fitted with a filter-paper 'mushroom' or on cloth covering the jar. Provided the cloth was kept moist with the food the latter system appeared to be the most satisfactory. A liberal supply of moisture in the form of droplets of water was deposited on the sides of the glass by means of a fine spray.

The results are shown in Table II, and it will be seen that neither starch nor albumen was of any use. Cane sugar solution was more successful, but the longevity varied greatly. The majority of the early deaths were males, however, which died soon after copulation. The 'composite' food appeared to be entirely unsuitable, although it contained cane sugar. The maximum longevity on a diet of cane sugar was thirty-four days, with a mean of five days, but the true mean for females was somewhat higher than this.

In the second series (Table III) diluted honey was supplied in the same way as the other foods, and was the most successful of any used. The mean longevity for both sexes was raised to nearly thirteen days with a maximum of thirty. Thinned honey would therefore appear to be the most suitable food at present known on which to keep these flies alive.

Table II.

Longevity of Adults.

Starch Solution.

				Longevity in Days.	
10 adults, emerging 2.9.25	10	died	3. 9.25 -	1	
20 „ „ 3.9.25	15	„	4. 9.25 -	1	*Range 1-1* *Mean 1.2*
	5	„	5. 9.25 -	2	

Albumen Solution.

10 adults, emerging 2.9.25	10	died	3. 9.25 -	1	
20 „ „ 3.9.25	15	„	4. 9.25 -	1	*Range 1-2* *Mean 1.6*
	5	„	5. 9.25 -	2	
44 „ „ 12.9.25	44	„	14. 9.25 -	2	

Sugar Solution.

10 adults, emerging 2.9.25	2	died	3. 9.25 -	1	
	4	„	5. 9.25 -	3	
	2	„	8. 9.25 -	6	
	1	„	11. 9.25 -	9	
	1	„	22. 9.25 -	20	
20 „ „ 3.9.25	1	„	4. 9.25 -	1	
	1	„	5. 9.25 -	2	
	1	„	7. 9.25 -	4	
	1	„	10. 9.25 -	7	
	6	„	14. 9.25 -	11	
	1	„	15. 9.25 -	12	
	2	„	18. 9.25 -	15	
	1	„	19. 9.25 -	16	
	2	„	20. 9.25 -	17	

SUGAR SOLUTION.—(*Contd.*)

				Longevity in Days.	
		3	„ 22. 9.25 -	19	
		1	„ 23. 9.25 -	20	
10 adults, emerging	4.9.25	2	died 11.9. 25 -	7	
		1	„ 15.9. 25 -	11	
		3	„ 16. 9.25 -	12	
		2	„ 17. 9.25 -	13	
		1	„ 19. 9.25 -	15	*Range 1-34*
		1	„ 22. 9.25 -	18	*Mean 5*
251 „	„ 6.9.25	83	„ 8. 9.25 -	2	
		160	„ 9. 9.25 -	3	
		1	„ 15. 9.25 -	9	
		2	„ 16. 9.25 -	10	
		3	„ 28. 9.25 -	22	
		1	„ 5.10.25 -	29	
		1	„ 10.10.25 -	34	
206 „	„ 7.9.25	109	„ 8. 9.25 -	1	
		89	„ 9. 9.25 -	2	
		4	„ 15. 9.25 -	8	
		3	„ 26. 9.25 -	19	
		1	„ 28. 9.25 -	21	
132 „	„ 8.9.25	46	„ 15. 9.25 -	7	
		26	„ 21. 9.25 -	13	
		17	„ 22. 9.25 -	14	
		20	„ 23. 9.25 -	15	
		22	„ 24. 9.25 -	16	
		1	„ 5.10.25 -	27	

"Composite Food."

						Longevity in Days.	
10 „	„ 2.9.25	1	„	5. 9.25 -	3		
		9	„	7. 9.25 -	5		
20 „	„ 3.9.25	1	„	4. 9.25 -	1		
		3	„	5. 9.25 -	2		
		8	„	8. 9.25 -	5		
		3	„	9. 9.25 -	6		
		2	„	10. 9.25 -	7		
		3	„	15. 9.25 -	12		
123 adults, emerging 5.9.25		95	„	6. 9.25 -	1		
		24	„	7. 9.25 -	2	*Range 1-12*	
		2	„	8. 9.25 -	3	*Mean 2*	
		1	„	9. 9.25 -	4		
		1	„	10. 9.25 -	5		
107 „	„ 9.9.25	99	„	10. 9.25 -	1		
		47	„	11. 9.25 -	2		
		24	„	12. 9.25 -	3		
		4	„	15. 9.25 -	6		
		3	„	21. 9.25 -	12		

Table III.

Longevity of Adults.

Honey and Water.

10 adults, emerging 3.9.25	1	died	5. 9.25 -	2	
	3	„	13. 9.25 -	10	
	3	„	15. 9.25 -	12	
	1	„	17. 9.25 -	14	
	1	„	19. 9.25 -	16	
	1	„	20. 9.25 -	17	

HONEY AND WATER.—(*Contd.*)

							Longevity in Days.	
115	„	„	4.9.25	3	„	8. 9.25 -	4	
				12	„	10. 9.25 -	6	
				2	„	11. 9.25 -	7	
				3	„	12. 9.25 -	8	
				33	„	15. 9.25 -	11	
				41	„	21. 9.25 -	17	
				4	„	23. 9.25 -	19	
				8	„	24. 9.25 -	20	
				2	„	25. 9.25 -	21	
				2	„	28. 9.25 -	24	*Range 2-30*
				3	„	30. 9.25 -	26	*Mean 12.7*
				1	„	1.10.25 -	27	
				1	„	4.10.25 -	30	
110	„	„	11.9.25	2	„	15. 9.25 -	4	
				3	„	16. 9.25 -	5	
				40	„	21. 9.25 -	10	
				13	„	22. 9.25 -	11	
				15	„	23. 9.25 -	12	
				11	„	24. 9.25 -	13	
				10	„	25. 9.25 -	14	
				4	„	28. 9.25 -	17	
				4	„	30. 9.25 -	19	
				1	„	1.10.25 -	20	
				1	„	5.10.25 -	24	
				1	„	10.10.25 -	29	

Natural Enemies.

PREDATOR.

Among other enemies of *Artona catoxantha* collected during 1925, the clerid, *Callimerus arcufer*, Chpn., occurred in small numbers. This beetle has been known to be predaceous on the larvae of *A. catoxantha*, but last year was observed to feed on the pupae of *Ptychomyia remota* as well. On discovering this, the larvae of the beetle were supplied with *P. remota* pupae in the laboratory and were successfully reared. The clerid must therefore be considered as an enemy of the tachinid as well as of *A. catoxantha*. Figure 6 is a sketch of the clerid larva feeding on the contents of a puparium of *P. remota*.

PARASITES.

(Hyperparasites.)

The mortality of the pupae of *Ptychomyia remota* during 1925 was remarkably large. This was due in large measure to the presence of numerous hyperparasites, but it also appeared that some fungous disease was present, a considerable number of pupae dying from no apparent cause. On dissection the interior of the latter was found to be full of mycelium. In addition, a number of pupae died owing to hyperparasites which failed to emerge. On former occasions it has been found that the pupae are very hardy, and the flies emerge under every possible condition, so that the mortality of pupae collected in the field was not due to unsuitable conditions in the laboratory.

From August 30th to September 13th 2444 pupae were collected. Hyperparasites emerged from 209 of these, while 1172 died. It was not possible to assign a cause of death to all these, but about 200 were dissected and found to be infested either by dead hyperparasites or a fungus. The mortality from all causes reached 100% on two occasions and rose rapidly from the first to the last collections. Unfortunately the collections were made concurrently with the collections of *Artona catoxantha*, and two days were missed owing to difficulties with the railway authorities. Of the nine hyperparasites found previously, six were again found last year, together with three which had not previously been observed. It must be remembered, however, that one (1809) was not available for comparison in the writer's previous paper, and that some of the hyperparasites which have been given separate numbers may be merely different sexes of the

same species. The comparative hyperparasitization by each is given below:—

TABLE IV.

Hyperparasites of Ptychomyia remota.

Record No.	Percentage parasitization.
1594	74.6
2616	7.1
1746	6.7
1497	4.2
1384	3.8
1747	2.0
1808	0.8
2750	0.4
2757	0.4

In Figure 9 the percentages refer to daily collections. The result of this is that the later collections show a much greater degree of parasitism than the earlier ones, since the number of *A. catoxantha* parasitized increases from day to day as the flies continue to lay. Similarly the degree of hyperparasitism of *P. remota* increases, partly because of the cumulative effect of the hyperparasites and partly because the emergence of the latter occurs after the date on which the flies would have emerged. Thus at the end of the period the flies have emerged from the healthy pupae, nothing but the hyperparasites remaining.

If the mean of the percentages shown in the chart in Figure 9 is taken for the whole period, it will be seen that the parasitization by *P. remota* was 35%, the figure obtained by actual count being 37%. The collection of caterpillars in the earlier stages, many of which would have become parasitized in nature but are included in the calculations as sound, would make this figure rather low, the true percentage being between forty and fifty. Similarly the mean for the hyperparasites works out at 60% for the period during which pupae were collected, the percentage on actual count being 57%.

Superparasitism.

During the last outbreak of *Artona catoxantha*, superparasitism by *Ptychomyia remota* occurred to an extent hitherto unknown. It is somewhat difficult to account for this, but the writer is of the opinion that in reality this parasite was markedly dominant, and would have terminated the outbreak had there not been such a high mortality during its pupal stage.

In one case as many as seventy-two eggs were found on one caterpillar, and in one area records were taken of parasitized caterpillars and the number of eggs on each. These are shown in Table V.

TABLE V.

Superparasitism.

72	eggs	were	observed	on	1	caterpillar
43	,,	,,	,,	,,	1	,,
18	,,	,,	,,	,,	1	,,
8	,,	,,	,,	,,	1	,,
5	,,	,,	,,	,,	4	caterpillars
4	,,	,,	,,	,,	9	,,
3	,,	,,	,,	,,	27	,,
2	,,	,,	,,	,,	63	,,

On dissection of a number of parasitized caterpillars with more than one egg, it was found that all the eggs had hatched, but that there was a marked discrepancy in the size of the larvae. Only one would be found which had increased in size in proportion to its age, the others being of varying sizes but all much smaller than the one dominant larva. The latter eventually reached maturity, all the others being delayed in their development and eventually dying. In many thousands of rearings, only one case has been observed of more than one larva emerging and pupating from one caterpillar. This occurred last year in August, and the two pupae gave rise to two normal adults.

Efficiency as a Parasite.

Daily collections of caterpillars were made during the outbreak of *Artona catoxantha* last year. Collections were made by native collectors who were unacquainted with the appearance of parasitized caterpillars, in order to avoid unconscious selective collection, and the pinnae of the coconut leaves were cut with the caterpillars on them and forwarded to the laboratory. In this way 10,852 caterpillars and pupae were examined between August 10th and September 13th. Unfortunately two days were missed during this period, owing to transport difficulties. There are two gaps, therefore, on September 4th and 7th which spoil the completeness of the records at the most critical period when the parasite was gaining the upper hand. At the end of the period the percentage of parasitism rose to over 80%, the percentages for the whole period being shown in Figure 9.

The efficiency of *P. remota* as a parasite is largely curtailed in the Malay States by the action of the hyperparasites, but despite this it is always capable of parasitizing its host to the extent of 30% to 40% and in most cases exceeds this figure.

It is quite possible that it will be required to check the activities of its host in islands in the Malay Archipelago where *A. catoxantha* has been accidentally introduced, and it is interesting to examine its capabilities. Wardle and

Buckle (Principles of Insect Control, 1923) ably summarise the requirements of a parasite to be introduced to control a pest. Very shortly, the parasite must be:—

1. Capable of controlling its host in its original habitat,
2. Capable of outnumbering its host,
3. Specific in its action,
4. Adaptable to fresh climatic conditions,
5. Capable of rapid dispersal,
6. Free from natural enemies, and
7. Unaffected by superparasitism.

Ptychomyia remota can always be expected to account for 30% to 40% of its host under ordinary conditions in the Malay States, and instances occur where it kills a much greater percentage than this. Although complete control has not been observed, it is by far the most important parasite under 'outbreak' conditions. On *Leruana iridescens* it has proved itself capable of parasitizing up to 80% and over when free of its natural enemies.

It is at present doubtful if the second requirement is complied with, since the exact numbers of eggs laid by the host and its parasite in nature are as yet unknown. The fact that there appear to be rather more females than males produced, however, would seem to show that under certain conditions it would be possible for *P. remotæ* to outnumber its host. 'Outnumber' is, of course, used here in an indeterminate sense, since the actual outnumbering of the host by a parasite of this nature would not occur.

A very large number of parasites has been reared in the laboratory from Malayan insects, but *P. remota* has only been obtained from *A. catoxantha*. Although it is possible to breed it on other caterpillars under artificial conditions, and although it is thought that other hosts may exist in nature, it certainly appears to be specific as long as *A. catoxantha* is present in large numbers.

Climatic conditions do not affect the situation in this case, because *P. remota* would only be introduced into localities having a climate similar to that in its original habitat. Indications are not wanting, however, that it is of a very hardy nature.

The power of dispersal would not appear to be very great as far as can be seen by its behaviour during outbreaks of its host. In Fiji, however, it appears to be diffusing well, and it will be interesting to see how it progresses in this respect.*

The numerous natural enemies which attack it in this country would appear to be an objection to its use as an introduced parasite, since it is generally considered that even

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*See Dr. Tothill's report abstracted in R.A.E. 14, p. 432:—
"In some cases 2 and 3 miles of open water have been traversed by the parasite in its dispersal".

if a parasite is artificially freed of its natural enemies, others will appear in the new habitat which will be capable of attacking it. This implies a polyphagous habit among hyperparasites, which occurs in the case of several of the enemies of *P. remota*. The principal enemy, Chalcid No. 1594, has so far only been bred from the one host.

Superparasitism may occur through the agency of other insects or owing to a habit of the parasite of depositing more eggs on one host than can possibly come to maturity. In the case of *P. remota*, however, one fly always emerges from a caterpillar which it has parasitized more than once, so that total extinction does not occur. A great waste of parasites results when superparasitism occurs, but it is not very common in this species.

On the whole, therefore, it may be said that *P. remota* is a fairly efficient parasite in its own habitat and that it offers good possibilities as an introduced parasite.

Resistance to Low Temperatures.

Previously, some experiments had been carried out to ascertain if it would be possible to keep the pupae of *Ptychomyia remota* dormant by subjecting them to low temperatures. On ice and at temperatures of 5°C and 10°C (41° and 50°F) all the pupae were killed except those from which the flies were due to emerge almost at once, when they did so without suffering any apparent injury. A batch placed in a commercial cool chamber said to be maintained at a temperature of about 13°C or 14°C (55.4° to 57.2°F) was also killed in a month, but in view of the experiments conducted in 1925 it is probable that sudden variations of temperature took place in this chamber.

In order to find out the effects of temperatures slightly below the mean daily temperature of the air, an apparatus capable of maintaining constant temperatures over a fairly wide range was required. This was easily constructed by the Public Works Department factory, and was designed on similar lines to the multiple temperature incubator employed in Egypt by Williams and Kirkpatrick.*

A copper tube, 204 cm long and 9 cm in diameter was sealed at the ends, one end being inserted into a water-bath and the other into an ice-box. The joins were made watertight by screwing the ends of the tube into plates rivetted to the sides of the water-bath and ice-box, the seams being further caulked with tow and white lead.

The exposed portion of the tube was drilled at intervals along the upper portion, there being 46 holes each 2 cm in

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*Ministry of Agriculture, Egypt, Technical and Scientific Service, Bulletin No. 38, Cairo, 1924.

diameter whose centres were 4 cm apart. This arrangement admitted the use of standard 3 x ¾ inch glass tubes and gave a variation in temperature of approximately 1°C per hole.

A wooden box was then built around the exposed portion of the copper tube and ice-box, and the spaces were packed with kapok. The lid of the box enclosing the tube was cut and made into seven small, easily removable covers, and the lid of the box surrounding the ice-box was secured by thumb-screws.

The insulating material along the upper portion of the tube and on the top of the ice-box consisted of kapok enclosed in muslin bags of such size as to conform to the lid under which each bag was placed, thus making small portions of the tube easily accessible without disturbing the remainder. The water-bath was insulated with asbestos board, and provided with the usual gas regulator and constant level water-tube. In practice a thermometer was kept in every seventh hole. Figure 7 is a diagrammatic section of the apparatus.

By keeping the water-bath at 59°C (138.2°F) a gradient in the tube from 49°C to 7°C (120.2° to 44.6°F), descending in steps of about 1°C was obtained (Figure 8). The loss of heat between the water-bath and hole No. 4 was considerable owing to the crude construction of the apparatus at that point, where danger from fire due to possible accident with the gas-burner had to be considered. The effective range of the apparatus was therefore between holes No. 5 and No. 46. The great efficiency of kapok as an insulator enabled a regular gradient, never varying by more than a degree, to be maintained. The consumption of ice was 15 lbs per day.

Some difficulty was at first experienced in keeping the water-bath at constant temperature owing to variations in the gas pressure due to the sun heating up the gasometer. This necessitated the use of a pressure regulating apparatus by means of which any gas over a given pressure was burnt at another burner.

After some preliminary experiments batches of ten pupae were placed between cotton-wool (to prevent condensed moisture remaining on the pupae) in corked glass tubes which were distributed along the incubator tube between temperatures of 19°C and 14°C (66.2° and 57.2°F) and the apparatus was closed down on August 29th. The incubator was opened again on September 13th and thereafter the tubes containing the pupae were examined daily. At 19°C five flies had recently emerged; at lower temperatures the emergence was proportionately delayed until at 14°C the last fly to emerge did so on October 1st, a period of 33 days, or 24 days beyond the last date on which it would probably have emerged if not subjected to this treatment. Between 16°C and 14°C (60.8° and 57.2°F) the average period from the time the pupae were placed in the incubator to the time when the flies emerged

was 27 days, the average for the ten flies at 19°C being 31 days. Details of the emergences at the various temperatures are given in Table 6.

TABLE 6.

Emergence at Varying Temperatures.

10 Pupae at each Temperature.			Placed in Incubator 29-8-25. Incubator opened 13-9-25.
Temp. °C.	Emergence Date.	No. of Flies Emerged.	Remarks.
19	13.9.25	5	Recently emerged.
	18.9.25	2	
	(1.10.25)	...	1 Hyperparasite
	...	...	2 Died
18	13.9.25	4	
	18.9.25	1	
	...	...	4 Died
17	13.9.25	4	
	20.9.25	3	2 Died as they emerged
	...	...	3 Died
16	18.9.25	3	
	22.9.25	6	2 Died as they emerged.
	...	...	1 Died
14	26.9.25	1	
	27.9.25	2	
	29.9.25	1	
	30.9.25	3	
	1.10.25	3	1 Died as it emerged.

These results show that it would be possible to delay the emergence of *Ptychomyia remota* for a sufficiently long period to enable the pupae to be transported over considerable distances. More work would have to be done on a larger scale before the technique could be perfected, and more accurate records would have to be obtained to ascertain the optimum temperature required. Although pupae of as nearly as possible the same age were selectd for experiment, the emergence was rather irregular and a number died. The correct age of pupae would also have to be ascertained. With a few more data, however, it would appear that this is the easiest way of keeping *Ptychomyia remota* alive for long periods.

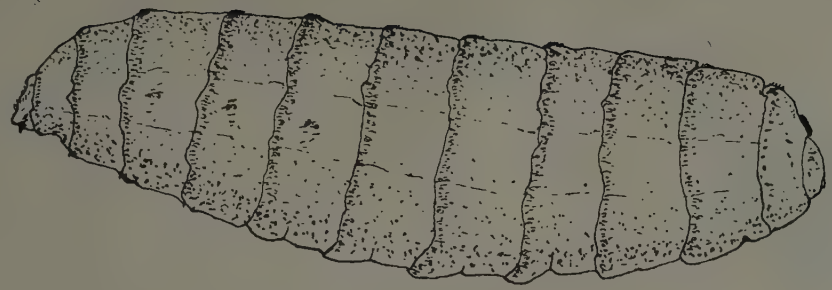


FIG. 1

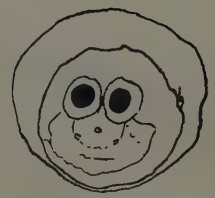


FIG. 2

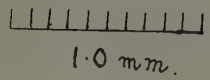


FIG. 3

FIG. 4

LARVA OF PTYCHOMYIA REMOTA.

Fig. 1. Mature larva about to emerge from host.

Fig. 2. Posterior view.

Fig. 3. Mandible.

Fig. 4. Stigmal plate.

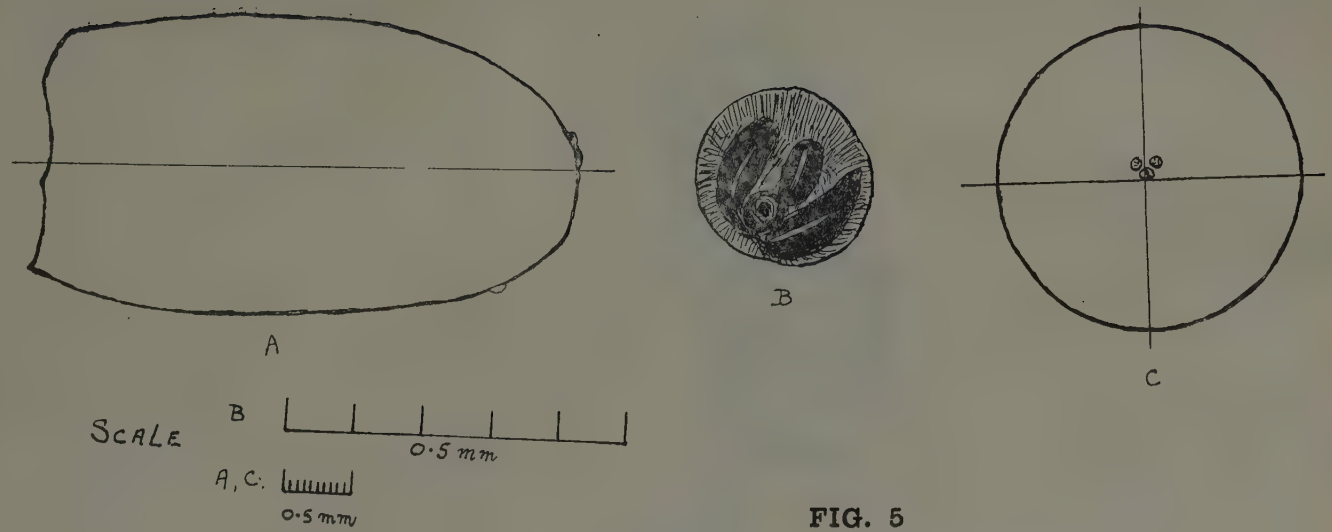


FIG. 5

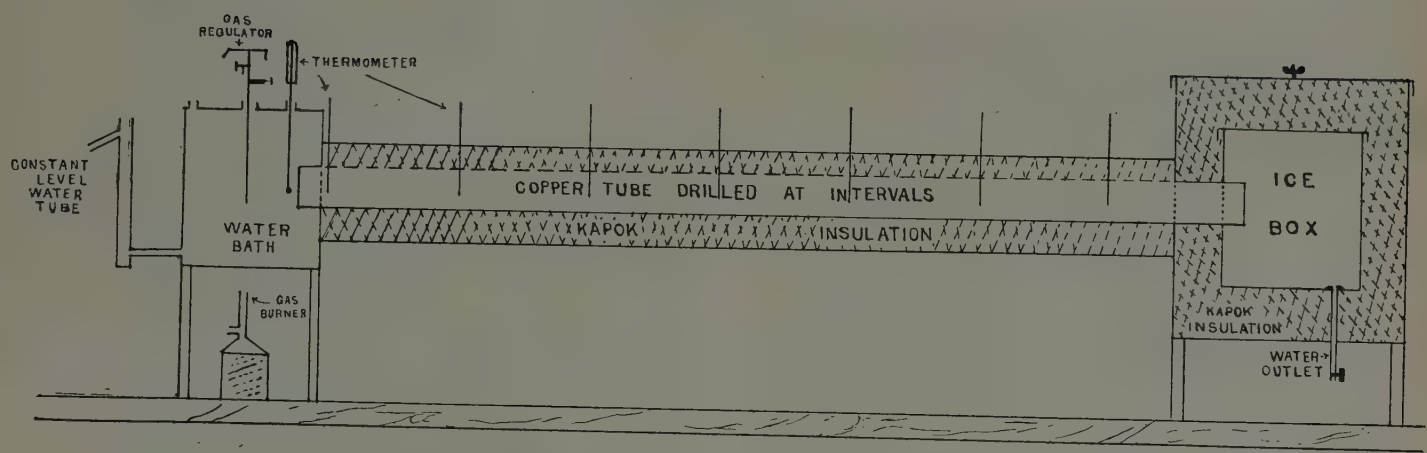
PUPARIUM OF PTYCHOMYIA REMOTA.

A. Side view.

B. Stigmal plate.

C. End view.

FIGURE 7



DIAGRAMMATIC SECTION OF MULTIPLE TEMPERATURE INCUBATOR

SCALE:— 5 10 20 30 40 50 CENTIMETRES

FIGURE 8

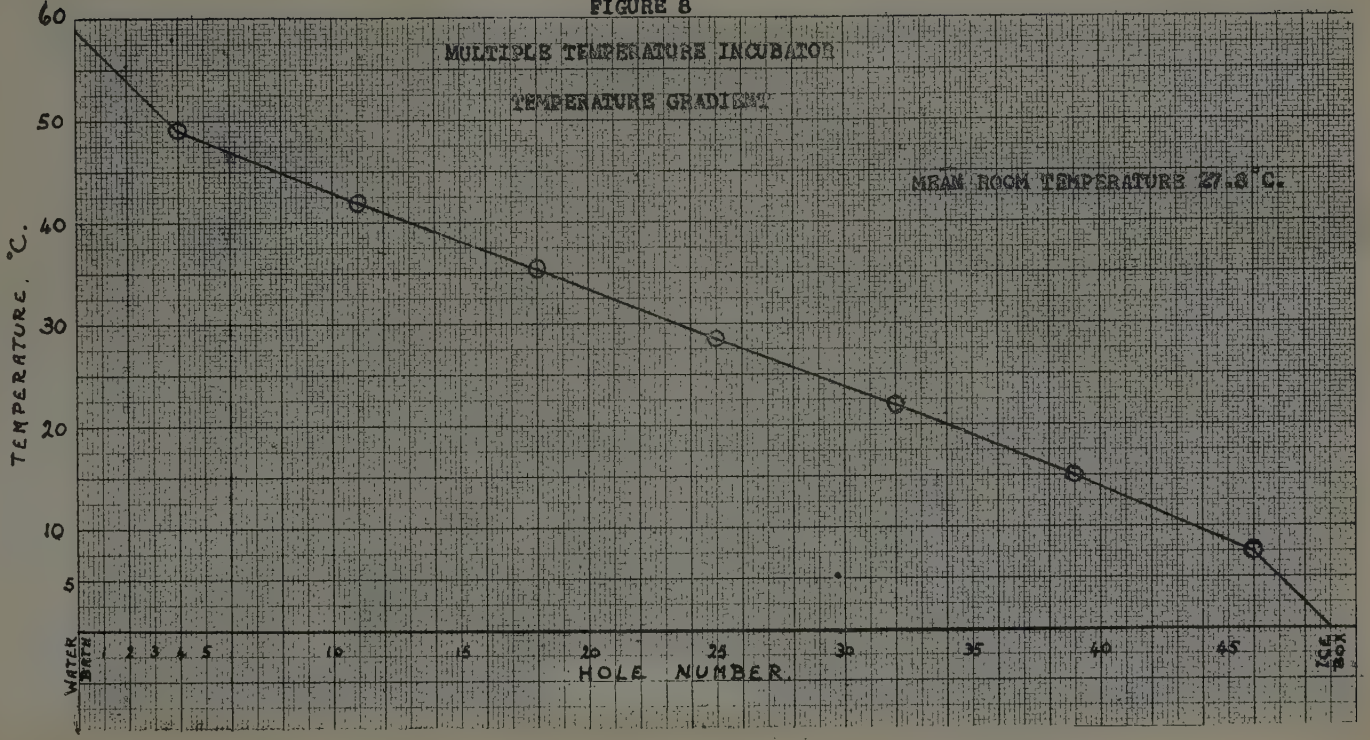

MULTIPLE TEMPERATURE INCUBATOR
TEMPERATURE GRADIENT
MEAN ROOM TEMPERATURE 27.8°C.
TEMPERATURE, °C.
60
50
40
30
20
10
5
WATER BATH
1 2 3 4 5
10
15
20
25
30
35
40
45
ICE BOX
HOLE NUMBER

FIGURE 9

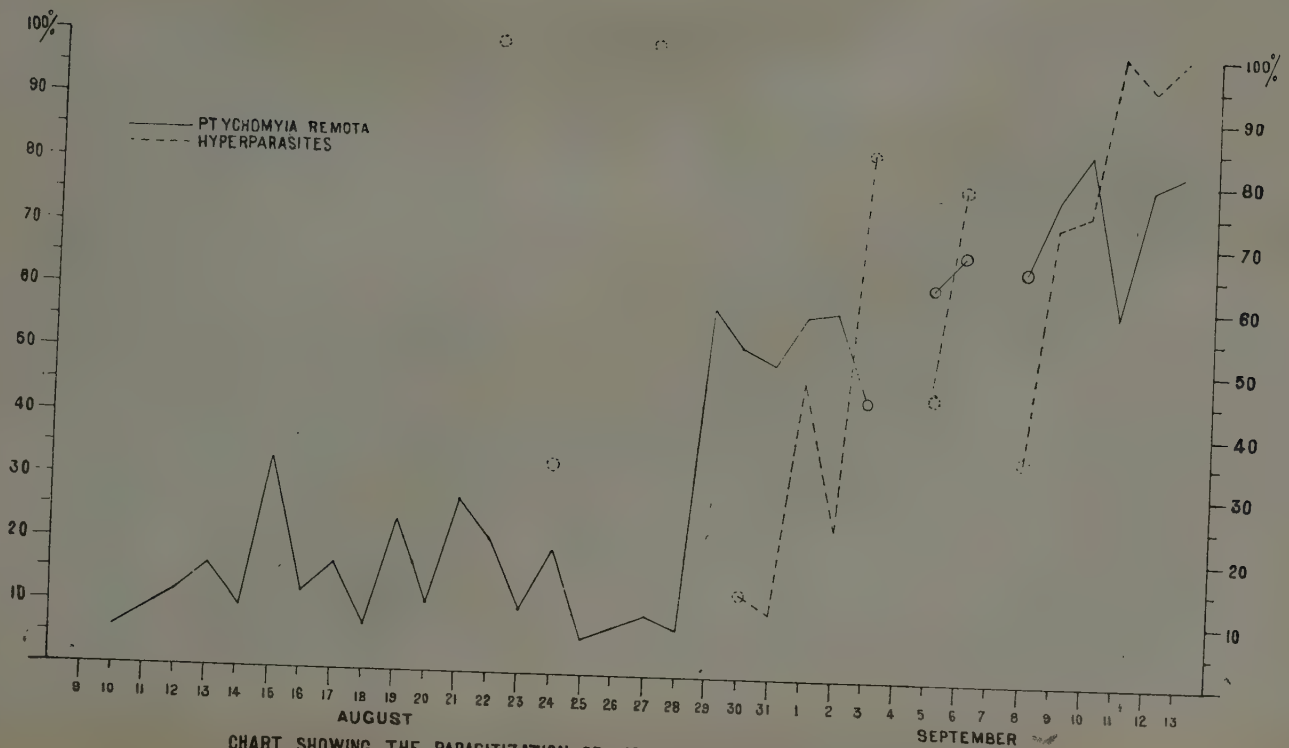


CHART SHOWING THE PARASITIZATION OF ARTONA CATOXANTHA BY PTYCHOMYIA REMOTA AND THE HYPERPARASITIZATION OF THE LATTER ON VARIOUS DATES

A PRELIMINARY NOTE ON "CHALCID NO. 1594", A PARASITE OF *PTYCHOMYIA REMOTA*, ALD.

B. A. R. Gater.

INTRODUCTION.

During the course of investigations on the Malaysian Coconut Zygaenid (*Artona catoxantha*, Hamps.) and its parasites, numerous hyperparasites have been found, short particulars of which will be found in the account of their hosts in the preceding papers. One, however, known at present as "Chalcid No. 1594", is an important parasite of the pupa of the tachinid, *Ptychomyia remota*, which is itself the most important parasite of *Artona catoxantha* in the Malay Peninsula. The activities of the tachinid are severely limited by this parasite and it would be most dangerous if it were introduced together with its host in cases where the latter was required for the control of a pest such as *Artona* or *Leruana* on coconuts. The ease with which it might be imported and some interesting features in its biology were the reasons for investigating its life-history, and the information so far accumulated is published as a part of the studies on *Artona catoxantha* and its parasites. Up to the present it has unfortunately not been possible to have this chalcid identified. Recently, however, Mr. H.M. Pendlebury, to whom the writer gave some specimens, communicated with Dr. Waterston and asked him if he would be able to undertake the identification of this single species. Owing to the short time remaining before the writer will proceed on long leave it has not been possible to wait for Dr. Waterston's reply, and this account is therefore published without the identification, which may be added later should Dr. Waterston be able to undertake the work.*

DESCRIPTION OF STAGES.

Chalcid No. 1594 (Figures 1 and 2) is a small black insect 0.9 to 1.0 mm. in length. The female is winged, slightly hairy and furnished with a fairly conspicuous ovipositor situated under the terminal segments of the abdomen. The male is wingless, has very small eyes and is clothed in long coarse hair which near the sutures of the abdominal segments is arranged in bands. The first segment of the antennae is very much enlarged, and the external genital organs are easily distinguished. In view of the possibility of an accurate systematic description being published by Dr. Waterson it is considered that the above rough general description is sufficient, together with the biological data, for the recognition of this insect in Malaya, and that further description is unnecessary at the moment.

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*Dr. Waterston has since written to Mr. Pendlebury as follows:—"The chalcid parasite from the pupa of *P. remota* is something very close to *Melittobia (Philopison) clavicornis* (Cam) though it is not the same species and may possibly represent a subgenus".

THE EGG.—(Figure 3) The eggs are nearly transparent when laid and somewhat difficult to find inside the puparium of the host. They are cigar-shaped with blunt ends, smooth and slightly greater in diameter near one pole. Length 0.22 mm., breadth 0.05 mm.

THE LARVA.—(Figure 4) The full-grown larva is 1.6 mm. in length and 0.45 mm. in breadth, smooth, with very indistinct segmentation and devoid of any organs or structures which can be seen in the fresh specimens. The younger, first-stage larva is more distinctly segmented, there being thirteeen visible segments, and nine pairs of spiracles may be seen on segments three to eleven. All stages are slightly curved and taper towards each end. It has not been possible to work out in what manner the larvae breathe, but it is thought that some form of sheath may be present which connects with the air, thus allowing the spiracles to function. In the case of the pupa this certainly appears to be the method of breathing.

THE PUPA.—The pupa is of the usual type and calls for little comment except that it appears to be enclosed in a transparent membranous sheath which is narrowed posteriorly into a tube. Lack of time has prevented the function of this sheath being investigated, but it is thought that the tube connects with some aperture in the puparium so as to admit air for breathing.

LIFE HISTORY.

The female of this species has been known to the writer for over three years, but it was not until an old puparium, from which females had emerged, was dissected during the course of investigations last year that the male was found. Previously it had been assumed that the females were parthenogenetic.

Newly-emerged females were enclosed in small corked tubes (3 x 5/8 inch) and fed on cane-sugar syrup on small pieces of filter paper. A pupa of *Ptychomyia remota* reared in the laboratory was placed in each tube, removed after twenty-four hours and a fresh one inserted. During the life-history work a continuous supply of fresh laboratory-bred pupae was available owing to the work proceeding on *Ptychomyia remota.*

Eggs are laid in batches of about twenty. The greatest number laid in twenty-four hours was seventy-one. They hatch in two to three days and the larvae live for six days before pupating. The pupal period lasts seven or eight days, making a total period of fifteen to seventeen days for the life-cycle. The mean period for the life cycle was found to be 16.7 days, but on one occasion it was reduced to 12 days and several cases occurred where it was prolonged to 30 days and over, the maximum being 35. This must have been due to some abnormal condition which was not ascer-

tained and these exceptional figures were not taken into account in calculating the mean.

Two methods of ascertaining the length of the various stages were employed. Firstly, the total period was obtained by offering *Ptychomyia* pupae daily and noting the time of emergence of adult females. Secondly, the egg, larval and pupal periods were obtained by offering a large number of pupae to a colony of females on the same day, a few parasitized pupae then being subsequently dissected daily. Table I shows the results for the total life-cycle; Table II contains similar information but is for the second generation, all the females employed having been reared in the laboratory. In Table III the results of the dissections are given.

TABLE I.

First generation.

CAGE 1.

1 Female emerged 16.8.25, died 15.9.25.

Pupa supplied -	18.8	20.8	21.8	25.8	26.8	28.8
Adults emerged -	4.9	7.9	6.9	9.9	12.9	14.9
Life-cycle (days) -	17	18	16	15	17	17
No. of Females -	4	6	13	11	14	14
No. of Males -	1	—	2	1	20	3
Total progeny from 1 female -	62 females 27 males.					

CAGE 2.

1 Female emerged 16.8.25, died 16.9.25.

Pupa supplied	18.8	21.8	22.8	23.8	25.8	26.8	28.8	29.8	30.8	31.8	1.9	6.9	7.9
Adults emerged	4.9	6.9	6.9	7.9	9.9	10 9	14.9	15.9	16.9	18.9	17.9	22.9	23.9
Life-cycle(days)	17	16	15	15	15	15	17	17	17	18	16	16	16
No. of Females	16	23	6	48	38	34	15	27	30	31	37	15	12
No. of Males.	2	1	—	1	1	3	2	2	1	3	2	8	17
Total progeny from 1 female.	332 females 43 males												

CAGE 3.

1 Female emerged 16.8.25, died 1.9.25.

Pupa supplied -	20.8	21.8	22.8	23.8	24.8	27.8
Adults emerged -	1.9	6.9	7.9	11.9	10.9	29.9
Life-cycle (days) -	12	16	16	19	17	34
No. of Females -	4	9	1	1	5	18
No. of Males -	1	—	—	—	1	1
Total progeny from 1 female -	38 females 3 males.					

CAGE 4.

1 Female emerged 16.8.25, died 30.8.25.

Pupa supplied -	22.8	23.8	24.8	25.8	28.8
Adults emerged -	7.9	7.9	9.9	9.9	14.9
Life-cycle (days) -	16	15	16	15	17
No. of Females -	11	12	7	24	16
No. of Males -	1	2	—	2	3
Total progeny from 1 female -	70 females 8 males.				

CAGE 5.

1 Female emerged 16.8.25, died 15.9.25.

Pupa supplied.	17.8	19 8	20.8	22.8	24.8	25.8	26.8	27.8	28.8	29.8	1.9	5.9	6.9
Adults emerged	4.9	4 9	5.9	6.9	9.9	10.9	29.9	29.9	2.10	16.9	19.9	27.9	22.9
Life-cycle(days)	18	16	16	15	16	16	34	33	35	18	18	22	16
No. of Females	7	4	26	10	15	30	15	35	20	5	8	5	25
No. of Males.	1	...	1	1	...	2	3	5	1	...	3	5	4
Total progeny from 1 female.	205 females 24 males.												

CAGE 6.

1 Female emerged 16.8.25, died 10.9.25.

Pupa supplied -	30.8	31.8	2.9
Adults emerged -	16.9	18.9	6:10
Life-cycle (days) -	17	18	34
No. of Females -	19	19	33
No. of Males -	2	2	5
Total progeny from 1 female -	71 females 9 males.		

CAGE 7.

Pupa supplied -	18.8	19.8	20.8	23.8	24.8	25.8	26.8	27.8	28.8	29.8
Adults emerged	4.9	4.9	4.9	8.9	9.9	9.9	11.9	12.9	15.9	2.10
Life-cycle (days)	17	16	15	16	16	15	16	16	18	34
No. of Females -	6	2	17	12	24	32	17	42	8	34
No. of Males -	—	—	1	—	1	1	1	2	2	5
Total progeny from 1 female	194 females 13 males									

TABLE II.

(*Second Generation*).

	Cage i A. 1 Female emerged 4.9.25			Cage ii A. 1 Female emerged 4.9.25.			Cage v A. 1 Female emerged 4.9.25.		
Pupa supplied -	4.9	6.9	8.9	4.9	5.9	6.9	4.9	5.9	6.9
Adults emerged -	21.9	22.9	22.9	21.9	22.9	23.9	21.9	22.9	23.9
Life-cycle (days) -	17	16	14	17	17	16	17	17	17
No. of Females -	23	67	40	29	19	56	21	11	68
No. of Males -	1	1	4	1	3	7	—	—	3
Total progeny from 1 female -	130 females 6 males.			134 females 11 males.			100 females 3 males.		

TABLE III.

Life history periods by dissection.

Puparia dissected.	Pupa supplied.	Eggs Laid.	Larvae appeared.	Larvae pupated.	Adults emerged.
20	4.9.25	4.9	7.9	13.9	20.9
10	5.9.25	5.9	7.9	13.9	21.9

TABLE IV.

Longevity of adult females.

(1) *Fed with syrup, no access to Ptychomyia pupae.*

5 Females emerged 5.9.25, 1 died on 14. 9.25
1 died on 24. 9.25
2 died on 4.10.25
1 died on 6.10.26

(11) *Without food.*

5 Females emerged 5.9.25, all died 10.9.25.

LONGEVITY.

The male dies shortly after all the females have emerged and been fertilized. When fed on sugar syrup and given full scope for egg-laying the longevity of females was from fourteen to thirty-one days, with a mean of twenty-five—(Table 1). When kept alone and given no opportunities for egg-laying the longevity varied from nine to thirty-one days, and when given no food or pupae in which to oviposit the period was reduced to five days (Table IV).

FERTILITY.

The maximum number of adults obtained in the breeding experiments from one female was 375, the total progeny from other individuals being 41, 78, 80, 89, 207 and 229 (Table 1). The second generation appeared to be more vigorous egg-layers than their parents, 136, 145 and 103 adults having been reared from three females each of which laid on three days only, the supply of *Ptychomyia* pupae having come to an end after this period (Table 11).

The female which produced 375 descendants laid this number over a period of twenty-one days in thirteen batches. Others laid three, five, six, ten and thirteen batches of eggs over periods of from seven to twenty-one days. The maximum number of adults from one day's laying in one pupa was seventy-one.

In the field the number of adults emerging from a single puparium varies between thirteen and eighty-two (females only), with a mean of twenty-eight. In order to find out what occurred if more than one female laid eggs in the same pupa two batches of ten females were taken and offered a single pupa. Twenty-four (three males) and sixteen (three males) emerged from these pupae respectively, so that the effect of such a procedure would appear to be small, the number of individuals produced depending on the food supply. In another case (Table V) two batches of three females laying in two pupae gave rise to 119 and 111 individuals. Whether superparasitism of this nature occurs in the field is unknown.

Proportion of Sexes.

The mean figure for all the breeding work shows a proportion of one male to nine females. The figure varied greatly, however, as will be seen by reference to Tables I and II. In one case only one male was present to sixty-seven females, while in another five of each sex emerged. In some instances no males were produced.

It is possible that the proportion of males to females works out in a more definite ratio in nature than occurred in the breeding cages, since by removing the pupa the female may have been interrupted in her laying just at the time when those eggs which were to produce males were being laid. As a whole it appeared that rather more males were produced towards the end of the egg-laying period.

Age of P. *remota* pupa required.

In order to ascertain at what age the host's pupa was most suitable for the development of the parasite, six batches of three females were given two pupae from two to seven days old. From the results shown in Table V it would appear that newly-pupated *Ptychomyia* are unsuitable up to three days old, and that the parasite can successfully complete its life-cycle on pupae which would normally produce adult flies in one or two more days.

Table V.

Age of Pupa Required.

Age of Pupa (days).	Date supplied.	Adult Parasites emerged.	No. of females emerging.	Length of Life-cycle (days.)
7	6–9–25	25–9–26	34	19
6	,,	24–9–25	51	18
5	,,	23–9–25	119	17
4	,,	23–9–25	111	17
3	,,	No result	—	—
2	,,	No result	—	—

HABITS.

The female is fairly active, but although quick in her movements on the coconut leaf does not readily take wing, flights when made being of short duration.

When *Ptychomyia* pupae are offered, the female is at once attracted and begins investigating by means of the antennae. During the twenty-four hours while pupae remained in the tubes with the females little notice was taken of anything else except during short intervals when food was taken. Egg-laying appears to take considerable time, and when once the ovipositor has penetrated the puparium the female remains in one position for many hours. Eggs are laid in batches, usually arranged so that the longitudinal axes lie in one direction, and are placed just within the puparium. The larvae may be seen lying one above the other after they have hatched, and as they increase in size they gradually fill up the space within the puparium, until by the time they have pupated practically the whole space is occupied. The pupae are packed very closely together, but in no particular order. On emergence the females make one or more small, round exit-holes in the puparium, and may be seen going in and out for some time before they actually leave their breeding place. It is during this period that fertilization takes place.

The males remain within the puparium and never emerge, dying shortly after all the females have been fertilized. Copulation was observed to occur several times with one female, the actual period of copulation being short. The male approaches the female from the front, climbs over her back and examines the terminal abdominal segments. He then turns round, brushing the female's eyes and antennae with his own. A few moments later the male curls his abdomen downwards, at the same time stretching out his fore-legs, copulation taking place in a semi-erect attitude.

NATURAL ENEMIES.

So far no definite information is available, but in a number of parasitized pupae taken in the field dead pupae of Chalcid 1594 were found together with another minute chalcid, similar in size, but differing slightly from No. 1594. The chalcid found under these conditions has not been found in other *Ptychomyia* pupae, and has only been found in association with No. 1594. Whether it is another form of No. 1594, or whether it is actually a tertiary parasite is as yet uncertain, but from the fact that many *Ptychomyia* pupae parasitized by Chalcid No. 1594 do not produce any adults but only some individuals of the other chalcid, it is very probable that the latter is indeed a tertiary parasite. The presence of a tertiary parasite would also account for the fact that although Chalcid No. 1594 has such good powers of reproduction and prevents a large number of *Ptychomyia*

Melittobia, prob. clavicornis, Cam.

reaching maturity, yet it never overruns its host as it would be expected to do.

EFFECT OF TEMPERATURE.

Chalcid No. 1594 emerged from puparia of *Ptychomyia remota* at all temperatures from 19°C to 33°C (66.2° to 91.4°F.) and previous experiments have shown that this insect will withstand still lower temperatures. It would therefore be possible to import the hyperparasite with the parasite if *Ptychomyia remota* were taken elsewhere in cool storage.

EFFECT ON PTYCHOMYIA REMOTA.

The mean reproductive power of a single female in the breeding experiments was 148, the proportion of females being nine to one. In three of these experiments the females had not ceased laying when the supply of pupae ran out, so that 150 eggs may be expected from one female as a fair average. One female, therefore, will produce a third generation numbering 2,460,375 females. Taking the average number of pupae killed by one female as 7, this will account for the death of 351,482 pupae. The result of importing one parasitized pupa, giving say 30 fertilized females, may well be imagined.

At the above rate *P. remota* would very soon be wiped out, but this degree of parasitization does not occur in nature. The reason for this is not at present very clear, but the presence of the possible tertiary parasite mentioned above is the probable explanation. As it is, the effect on *P. remota* is fairly serious. From the material collected during 1925 Chalcid No. 1594 only emerged from 8% of the pupae, but in reality a much greater percentage than this was parasitized, and it was not realised until too late for the accumulation of data that other factors were coming in.

FIG. 1

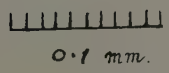
FIG. 2

CHALCID 1594.

Fig 1. Male x 50
Fig 2. Female x 50

[illegible] – [illegible] clavicornis, [illegible]

FIG. 3



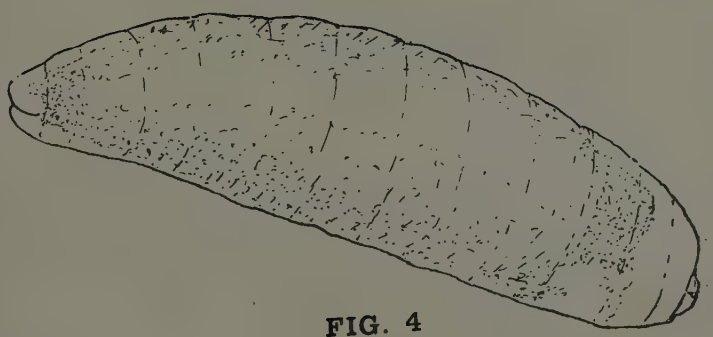
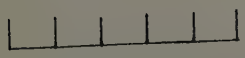


FIG. 4



CHALCID 1594.

Fig 3. Egg.
Fig 4. Larva.

"*ARTONA CATOXANTHA* AND ITS PARASITES"

SUMMARY.

The foregoing papers, which are supplementary to one already published, deal with some aspects of the *Artona catoxantha* problem. They are records of unfinished work, and although it is rarely wise policy to publish results of this nature, it is thought that a report of the progress made should be presented in collated form because circumstances will not admit of the writer investigating the problem further. Therefore, it should be emphasized that the results, especially those relating to the parasites and their inter-relations, refer to the conditions obtaining during the particular outbreak examined and are not in any way to be taken as conclusive.

From the investigations on *Artona catoxantha* three points of economic importance have so far arisen:—

(a) Although not proven, it appears that in some way fires under the palms are connected with outbreaks of the pest.

(b) As far as it has been possible to ascertain the best time for the application of artificial control measures is during the first and early second instars, when the caterpillars are not attacked by parasites. Artificial control will thus be supplemented by natural control when the later instars are attacked.

(c) The study of one of the parasites, *Ptychomyia remota*, aided in it being introduced into Fiji for the control of a serious coconut pest, *Levuana iridescens*.

The following is a short summary of the ground covered in the three papers:—

1. The life-history of *Artona catoxantha* was more fully investigated and the previous figures checked. Some of the immature stages are more extensively described.

2. Records of the occurrence of known parasites and a note on four previously (?) unrecorded parasites are given. A new predator from British North Borneo is mentioned.

3. Rough descriptions are given of some of the larval stages of *Callimerus arcufer*, Braconid No. 1085 and of a hyperparasite affecting the latter. Five hyperparasites affecting Braconid 1085 are also recorded. The difference in the puparium of *Degeeria albiceps* from that of *Ptychomyia remota* is described.

4. The percentage parasitization and the inter-relations of parasites are discussed. *Ptychomyia remota* is the most important natural enemy.

5. The larva and puparium of *Ptychomyia remota* are described, and some further details of its life-history are given.

6. *Callimerus arcufer* is recorded as being predaceous on the pupae of *Ptychomyia remota*, and three previously (?) unrecorded hyperparasites affecting the pupae of this fly are mentioned.

7. The question of superparasitism on the part of *Ptychomyia remota*, the relative importance of the hyperparasites affecting it, and its efficiency as a parasite are discussed.

8. It was found that the pupae of *Ptychomyia remota* could be kept dormant for over thirty days at a temperature of 14°C.

9. A chalcid parasite of the pupa of *Ptychomyia remota* is described and its life-history given.

10. The life-cycle of this parasite occupies sixteen to seventeen days, the average number of eggs laid is 148 and the proportion of females to males is 9:1.

11. This parasite is a serious enemy of *Ptychomyia remota*, but it is believed that its activities in Malaya are limited by the presence of a tertiary parasite.

The writer is indebted to Enche Mohamed Yusope for continuous help throughout the course of these investigations; to Mr. K. Anthony for numerous drawings, and to Mr. Keng U for the loan of a photographic lens which made the reproduction of the plate accompanying these papers possible.

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